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PRACTICAL GAS-FITTING

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(Including Gas Manufacture)

WITH NUMEROUS ENGRAVINGS AND DIAGRAMS

EDITED BY

PAUL N. HASLUCK

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EDITOR OF "WORK" AND "BUILDING WORLD"
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PHILADELPHIA

DAVID McKAY, PUBLISHER

1022 MARKET STREET

1903

PREFACE.

PRACTICAL GAS-FITTING gives, in a form convenient for everyday use, a comprehensive digest of information, contributed by experienced writers, and scattered over the columns of BUILDING WORLD, one of the weekly journals it is my fortune to edit, and supplies concise information on the general principles and practice of the subjects on which it treats. Chapters on gas manufacture, on incandescent lighting, and on stoves for warming and cooking, are included.

In preparing for publication in book form the mass of relevant matter contained in the volumes of BUILDING WORLD, much of it necessarily had to be re-arranged and re-written. From these causes the writings of many contributors are so blended that it is difficult to distinguish any for acknowledgment.

Readers who may desire additional information respecting special details of the matters dealt with in this book, or instruction on any building trade subjects, should address a question to BUILDING WORLD, so that it may be answered in the columns of that journal.

P. N. HASLUCK.

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PRACTICAL GAS-FITTING.

CHAPTER I.

MANUFACTURE OF COAL GAS

GAS has, nowadays, a vast number of valuable applications. Its usefulness is apparent in many manufactures ; it is employed for the supply of power, heat, and light ; it is reliable and comparatively cheap, and is equally suited to supply the power that works an engine of 150 horse-power or the small jet of flame that lights a cigar. That gas is used largely at the present day is obvious when it is stated that in England alone about 10,000,000 tons of coal are used annually for gas-making, and of this quantity about one-fourth is used in London—one company that lights the larger portion of London north of the Thames purchasing more than two million tons. The total annual income of the metropolitan gas companies amounts to about four millions sterling ; and in London alone there are more than 2,000 miles of gas-pipes.

The first thing to arrange in a gasworks is an easy means of transit for the purpose of getting the coals to the store ; and the means of transit varies according to the extent of the operations. Where the works are very large, it is necessary to make provision for the simultaneous unloading of several large steam vessels ; whilst in small country works all the coal is brought by cart and shot in the yard close to the retort-house. Indeed, the details of this matter depend so largely on local circumstances that further reference to it here would be superfluous.

Bituminous coal is best for gas-making purposes ; caking cherry, and splint coals are of this character. Suitable coal is found in many places in the United Kingdom, but most abundantly in Northumberland, Durham, Yorkshire, and Lancashire.

The products obtained in the manufacture of coal gas are the illuminating gas, the coke which remains in the retort after the gas is driven off, the ammoniacal liquor, and the tar. With regard to the quantities of such products obtainable from a ton of coal, it is difficult to give an exact statement, as the amounts are influenced by numerous considerations, such as the character of the coal, the temperature at which it has been distilled, etc. Common coals are usually classed as those which give on distillation a volume of gas of 9,800 cub. ft. to 11,000 cub. ft. per ton, the illuminating power of the gas ranging from 14 candles to 17½ candles, and cannel coals as those yielding from 10,000 cub. ft. to 15,000 cub. ft. of gas per ton, of an illuminating power ranging from 20 candles to 45 candles or 50 candles. Owing to the numerous varieties of common coal and cannel in the market, it is almost impossible to give an average yield of the products obtainable from each description, but the following figures from Newbigging's "Gas Managers' Handbook" will afford some indication of the different amounts. Wigan cannel and common coal yield on an average per ton :—

	Cannel.	*Common Coal.*
Gas	10,900 cubic ft.	9,980 cub. ft.
Illuminating power	24 sperm candles	15 candles.
Coke	14·36 cwt.	15·17 cwt.
Tar	17 gallons	11 gallons.
Ammoniacal liquor	18 gallons	20 gallons.

Newcastle coal yields on an average per ton :—

Gas	9,700 cub. ft.
Illuminating power	15 sperm candles.
Coke	15·40 cwt.
Tar	9 gallons.
Ammoniacal liquor	10 gallons.

Of course, some of the rich Scotch cannels would yield more gas and of a richer quality than Wigan cannel; for example, Thorburn coal yields 13,120 cub. ft. of gas per ton, of an illuminating power of 36 candles. In practice it has been found that a ton of ordinary Newcastle coal yields roughly :—Gas, 10,000 cub. ft.; coke, 13 cwt. to 14 cwt.; tar, 10 gal. to 12 gal.; virgin ammoniacal liquor, 16 gal. to 18 gal. The richest and finest gas coal is brittle and friable. It has a greyish-black, shiny, resinous

lustre, and is made up of laminations or layers of varying thicknesses. The common coals are practically a mixture consisting of two descriptions of coal. The first is a bright glistening material, somewhat resembling black glass, and having in the thicker lamination a cross fracture that is more or less cubical. The second variety is of a duller appearance, somewhat resembling charcoal. The relative proportions of the glassy coal, which is known as jet coal, and of the duller variety, which is called smut coal, determine the character of the bulk. Evidences of smut are to be found in every laminated coal, and traces of it may also be found in cannel. The bright coal is much richer in hydrogen than the smut coal, and contains less ash. Very hard coals are built up of alternate laminations of bright coal and of charcoal. The finest caking coals do not contain more than 2 per cent. of ash, which should be light, similar in structure to the ash obtained from wood, and varying in colour from white to a brick-red. In the term cannel are included all hard, non-laminated coals having a homogeneous character. When they give a flaky fracture and have an earthy appearance, they are known as shales. The richer classes of cannel are dull and brown, the poorer or secondary cannels are generally bright and black, and the poorest description are generally dull and black.

Cannel coal is used principally in gas manufacture to enrich common coal, so as to bring up the illuminating power of the gas produced from the latter description of coal to the necessary degree. For instance, London gas must have an illuminating power of not less than sixteen candles when tried at the testing station, and this requirement implies that the gas leaving the works must have an illumination power of not less than seventeen candles ; and as the Newcastle coal from which the bulk of London gas is made will only produce gas having a power of from fifteen to fifteen and a half candles, the coal must be enriched by some means, of which the use of cannel is one. Modern substitutes for the use of cannel are—the mixing of the gas made from common coal with a certain proportion of rich gas made from oil, the method of effecting this being by the adoption of the Peebles process of gas-making, invented by Mr. Young of Clippens (the oils employed should be of a specific gravity of 850 to 890, and they are vaporised by the heat of steam in a carburetter ; or oil gas can be made in special iron retorts and then mixed with coal gas) ; by mixing a certain proportion of

carburetted water gas with the coal gas; or by the adoption of the Maxim-Clarke system, which consists in impregnating gas with the vapour of certain volatile hydrocarbons, such as carburine or benzol. The method which is most commonly adopted in English gasworks, in order to enrich gas otherwise than by means of cannel, consists in mixing the gas produced from common coal with a certain proportion of carburetted water gas. Water gas is produced by passing steam over red-hot coke, the result of the decomposition of the steam being a mixture of carbon monoxide (CO) and hydrogen, and theoretically there should be obtained equal volumes of the two gases, but in practice this result is not obtained, there being always present a certain amount of carbon dioxide (CO_2). The following equation shows the reactions involved :—

$2\ H_2O$ (in the form of steam) $+ 2\ C$ (coke) $= H_4 + 2\ CO$.

Cannel coal is also useful in an emergency, as when the holders are suddenly found low, as it gives off its gas in much less time than ordinary coal.

True cannel coal does not cake, but yields on distillation a residue similar (with the exception of some cracks and fissures) to the original material. These cracks, however, indicate the laminated structure, which was not visible in the original cannel. The amount of ash from cannel is greater than that from coking coals, and often shows the laminated structure more clearly than the coke. As compared with coking coals, cannels yield tar of a lighter specific gravity, and more of it. Although the physical difference between common coal and cannel is well marked, the chemical difference is not so apparent, certain cannels having precisely the same elementary composition as some coking coals. As a rule the sulphur and the carbonic acid impurities are lower in cannel than in coking coals.

Coal analysis embraces the determination of moisture, ash, sulphur, volatile matter and coke, and in order to effect such determination the apparatus required would be: a balance with weights, watch-glasses and clip, platinum crucible, and water-oven. The balance is used for weighing out the coal to be operated on, and consists essentially of a rigid beam suspended near to and slightly above its centre of gravity. Suspended from each end of the beam, and equidistant from its centre, are the scale-pans. In order to diminish the friction at the points of suspension the beam is provided with an agate knife-edge which works on an

agate plane, the scale-pans being similarly suspended. The beam of the balance is supported by a rest when not in use, and is raised from its support by a milled-head disc. It is provided with a pointer and an ivory scale for the purpose of indicating the movements of the beam. The object to be weighed is placed in the pan on the left-hand side of the balance, the weights occupying the opposite pan. The watch-glasses and clip are employed for the purpose of holding substances whilst weighing out for analysis, and in the case of coal analysis they serve to hold the coal in the experiment for the determination of moisture; 100 grs. of coal are weighed out into the two watch-glasses, the coal and glasses are then placed in the water-oven, and weighed at intervals. While weighing, the glass containing coal is covered by the other, and the two are placed between clips to prevent contact with air.

The water-oven in which the coal is dried consists of a copper vessel having, with the exception of the door, a double casing. When in use, the casing of the oven is filled to about three-fourths of its height with water. Heat is then applied by means of a Bunsen burner, so that when the water boils the upper part of the hollow casing becomes filled with steam, and the interior of the oven attains a temperature of 212° F., which is constantly maintained; a gentle stream of air then passes through the oven, drying the substance in the interior.

The platinum crucible is employed in the first place for determining the amount of volatile matter, coke, and ash in the coal. To determine the volatile matter and coke, about 2 grs. of the finely powdered coal is spread out in an even layer on the bottom of a weighed platinum crucible. The latter is covered with a lid and placed on a pipeclay triangle over a Bunsen burner. The gases issuing from beneath the lid take fire, and the heat is continued for one minute longer than the gas flame lasts. Then the Bunsen burner is removed, and the crucible is allowed to cool, and, when cold, is weighed without the lid. The weight obtained will represent the coke, and this subtracted from the weight of the coal originally taken will give the volatile matter.

To determine the amount of ash, from 3 grs. to 5 grs. of coal is placed in a shallow layer in an open platinum crucible, and heated by a Bunsen burner until all carbonaceous matter is consumed.

The platinum crucible is also employed in the determination of sulphur in the coal. In the first place about 10 grs. of coal is mixed with a suitable fusion mixture and heated in the platinum

crucible; when all carbon has been consum d, the mass is allowed to cool, and when cold is extracted with distilled water. The solution is then acidified with HCl (hydrochloric acid), and boiled, and the sulphuric acid is precipitated with barium chloride, filtered, and washed; the precipitate is then placed in the platinum crucible and ignited, and when cold is weighed. From the weight of $BaSO_4$ (barium sulphate) is obtained the amount of sulphur in the coal.

The first process in the manufacture of coal gas consists in subjecting bituminous coal or cannel to the action of heat in a closed vessel termed a retort. The operation is chemical, and is known as destructive distillation, but in gasworks language is spoken of usually as carbonisation. The effects of heat on coal under the conditions mentioned are that the elementary components of the coal are split up, and rearrange themselves to form a large number of new bodies, which make up the gas, coke, tar, and other products evolved during the process of carbonisation. The retorts in which the coal is placed are usually made of fireclay, to enable them to withstand the high temperatures to which they are subjected. The internal dimensions of retorts vary from about 16 in. to 22 in. wide, 13 in. to 16 in. high, and from 9 ft. to 10 ft. long, the thickness of the vessel being 3 in. in the body and 4 in. at the mouth. Retorts are made of various shapes in cross-section, the principal being round, oval, and, commonest of all, D-shape. They are set horizontally in groups in a series of firebrick arches, termed benches, and are heated by a furnace and a series of flues connected to a main flue and chimney. The number of retorts placed in the arches varies from two to nine or more, according to the size of the works. (Fig. 1 shows a section of a retort setting) At each end of the retort is a cast-iron mouthpiece with door B, sealed by a mixture of soap ash, or clay and ashes, or by the self-sealing lid described on p. 19; this lid is made by the jointing of two turned faces pressed closely together by a cross-bar and cam, and has an outlet pipe D on the upper side, through which the gas travels. The retort when hot enough is filled by scoops, as described on p. 23, with about 3 cwt. of coal, which is laid in a fairly even layer over the lower surface; the door is then tightly closed, and the gases can escape only by the rising pipe on top of the mouthpiece, the coal being usually allowed to remain for six hours in the retorts. Seven is the number of retorts generally grouped together in retort house

in medium-sized works on the ground-floor principle, where the furnace is on the same level as the floor from which the retorts are charged; while, in stage-floor houses provided with a coke hole below the charging floor, it is usual to place the furnace in the coke-hole, which has the effect of providing room for nine retorts or more. A group of retorts disposed as described is known as a bed or setting of retorts, while a continuous line of arches containing settings is known as a bench.

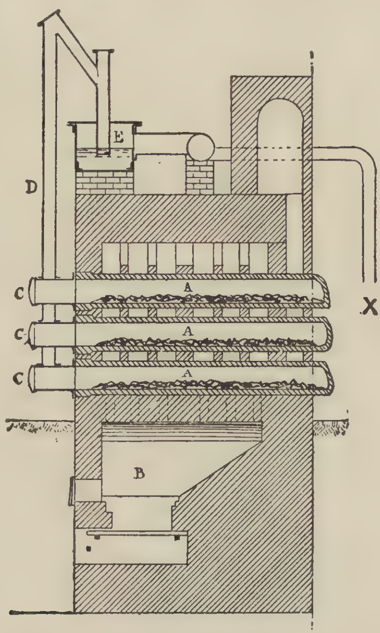


Fig. 1.—Section of Retort Setting.

Fig. 2 represents an outline sketch of a stage retort house. The building is 70 ft. wide between the walls, which leaves a space of 25 ft. on each side between the walls of the house and the front of the settings, which are 20 ft. "throughs" (described on p. 18). The coal stores on each side are 15 ft. wide. The charging-stage is 10 ft. above the coke-hole floor, which is paved with bricks on

edge on a layer of concrete 12 in. thick. The depth of the foundation of the walls will depend on the bottom met with. The roof is formed as shown, each principal being 8 ft. 6 in. from centre to centre. The stage is constructed of wrought-iron girders, built into the wall of the house and into the division wall, off-setting and resting on a column, as shown. The main girders are 16 in. deep, placed about 10 ft. from centre to centre, and the floor is constructed of cast-iron flanged plates, bolted together. The columns supporting the girders are 9 in. diameter at the bottom, tapering to 7 in. at the top, and of ⅞-in. metal. The railway is supported by girders resting on columns, as

Fig. 2.—Stage Retort House.

shown. The height from the charging-floor to the wall-plate is 40 ft.

Fig. 3 shows a sectional elevation, and Fig. 4 a longitudinal section, of eight single retorts heated by a regenerator furnace. The retorts are 22 in. by 16 in., and 10 ft. long. The producer A is provided with upper and lower doors, the upper being the charging door and the lower the clinkering door. In the arch of the producer a number of small openings are formed as shown, through which the combustible gases pass to the combustion chamber. Placed on each side of the outer part of the producer is the regenerator B; the direction of the air and gas is vertical in both cases, the spent gases descending through the

centre chamber, while the secondary air ascends on each side of the spent gas chamber; the two air passages join at the top end of the regenerator to meet the issuing combustible gases from the producer. The products of combustion travel over and around the middle and top retorts, then descend and travel under the bottom retorts, finally entering the regenerator, whence they pass to the main flue, heating the secondary air in their course. The air necessary for the production of the combustible gases, and known as the primary air, is heated by one or more of the lower passages before entering the producer. The scientific principles involved are as follows:—On filling the producer A with coke, and drawing in a regulated amount of air, the carbon of the fuel combines with the oxygen of the air to form carbon dioxide (CO_2), the position where this chemical action takes place being known as the zone of combustion. The CO_2 loses some of its oxygen whilst passing upwards through the thick mass of fuel contained in the producer, and becomes carbon monoxide or carbonic oxide (CO)—thus, $CO_2 + C = 2CO$. The carbonic oxide, which is a combustible gas, attains a temperature of about 2,000° F. in the producer, and passes out through the openings in the producer arch into the combustion chamber. At the point where it emerges from the producer, it meets the heated secondary air, which has been raised to a temperature of about 1,800° F. by passing through the generator B as previously explained, the result being that the carbon monoxide is again burnt to carbon dioxide—thus, $CO + O_2 = CO_2$—the resulting products of combustion giving out a heat of about 2,500° F. The products of combustion then travel through the setting, giving out heat to the retorts in their passage, and finally enter the regenerators at a temperature of about 1,900° F.

The retorts are heated either by a furnace immediately under them on the open-grate system, or by a producer into which only a small portion of the oxygen of the air is allowed to enter. In the latter system, the oxygen, combining with the carbon, forms, as already explained above, carbon monoxide, and a further portion of air, previously warmed by the waste gases as they leave the setting, is arranged to enter and mix with the carbon monoxide and form carbon dioxide immediately under the lower retorts; and thus the greatest amount of heat is obtained where it is required, and not, as in the open-grate system, in the furnace. Dr. Siemens was the first to recommend this arrangement, which

is the same in principle as the furnaces in use for smelting iron.

The benches of retorts are usually made double—that is, back to back, and frequently the retorts are continuous for a length of from 18 ft. to 22 ft., having a mouthpiece at each end. The retorts are then known as "through," in distinction to the

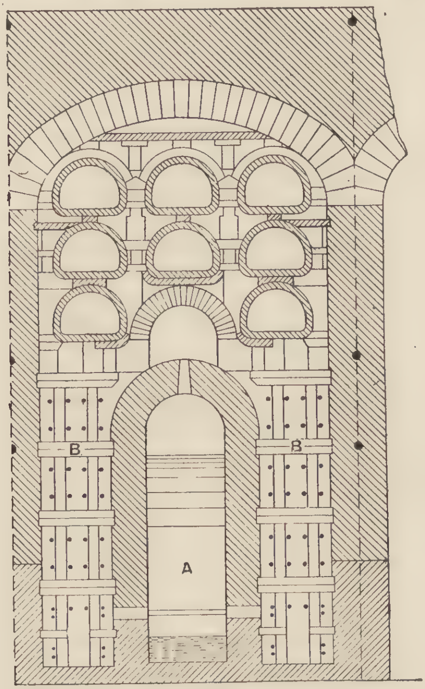


Fig. 3.—Sectional Elevation of Eight Single Retorts.

"singles," which have only one mouthpiece, their back ends being closed. With the exception of this community of retorts, the settings are distinct, and have separate flues and furnaces. An iron mouthpiece, bolted on to the clay mouthpiece of each retort, projects out about 16 in. from the front of the setting, and serves to support the lid that shuts off the retort from the atmosphere during the operation of drawing and charging. There are two

descriptions of lids employed in gasworks: one is of plate-iron, and is made tight by means of a luting composed of spent lime and clay, the lid being screwed against the face of the mouthpiece. But, in modern works, self-sealing lids are employed; these have the rim faced and planed, the mouthpiece being similarly treated; the lid swings round on a swivel hinge, and is

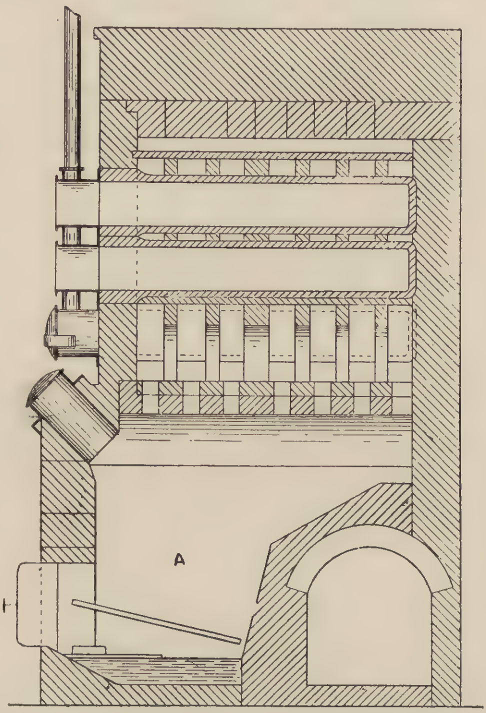


Fig. 4.—Longitudinal Section of Eight Single Retorts.

made tight against the mouthpiece by means of an eccentric lever. The mouthpiece is provided with an opening into which fits an upright pipe, known as the ascension pipe, which is connected to the arch or saddle pipe, and the latter in turn to the dip pipe which conducts the gas from the retort to the hydraulic main, where it is prevented from returning to the retort.

Figs. 5, 6, and 7 represent a setting of three retorts heated on a modern system by means of a regenerative furnace; the system has been found to give good results in practical working. The producer is placed inside the oven under the front of the retorts, and is 2 ft. square inside by 3 ft. 6 in. deep. The waste-gas flues forming the regenerator are four in number, and 9 in. square; they occupy the rest of the oven space, and extend 3 ft. outside the back of the oven, where they are carried to the chimney by a cross flue. As shown in Fig. 5, the regenerator is so arranged as to form three sets of flues, the top and bottom sets being for the waste heat passing from the oven to the chimney, and the middle set for the heated air. The air for the hot-air flues is admitted at the back of the regenerator, and is carried forward by two 4-in. fireclay pipes to nearly the front end

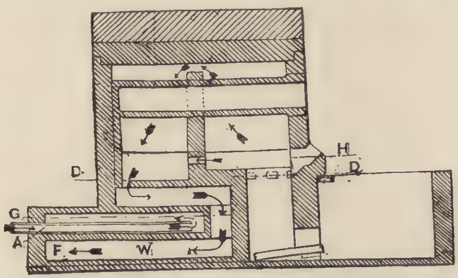


Fig. 5.—Longitudinal Section through Oven.

of the two centre air-flues. It goes back outside these pipes, but still in the two centre flues, and returns to the front in the two outside air-flues, entering the top of the producer by three ports at each side. The combustible gases from the producer combine with the heated air, and pass up the front portion of the retorts, over a middle wall, down the back portion, and then enter the upper set of flues, in which they travel forward and descend to the lower set of flues, and thence to the main flue leading to the chimney. The primary air is admitted at the door at which the producer is cleaned out. Fig. 5 represents a longitudinal section through the oven; Fig. 6 is a horizontal section on the line G H, Fig. 5; Fig. 7, a vertical section on the line J K, Fig. 6. A denotes the air-flues, D D the floor line F flue, and W waste heat.

It is necessary to test frequently the producer and flue gases

in order to ensure that the correct amount of primary and secondary air is being admitted to the setting, otherwise there will be a considerable waste of fuel. In the case of the producer gases, an excess of primary air implies the production of carbonic acid instead of carbonic oxide, and in the case of flue gases an excess of secondary air implies a cooling of the setting, while a deficiency denotes a waste of fuel due to carbonic oxide escaping

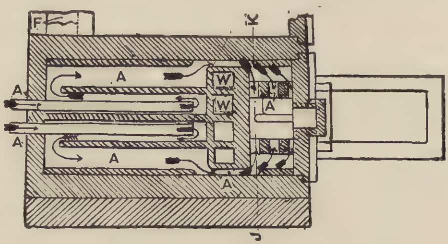


Fig. 6.—Horizontal Section through Oven.

unconsumed. The theoretical composition of producer gas is 34·7 per cent. carbonic oxide, and 65·3 per cent. nitrogen, but this result is never attained in practice, as hydrogen is always present, due to the decomposition of the steam given off from the water

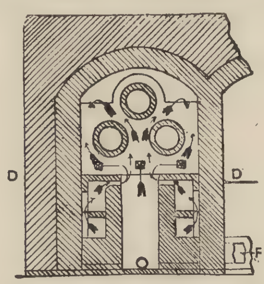


Fig. 7.—Vertical Section through Oven.

in the ash-pans, while the reduction of carbon dioxide CO_2 (to carbon monoxide CO) in the producer is never complete, with the result that some CO_2 is always present in producer gas, but it should never be allowed to exceed 6 per cent. The flue gases should consist of CO_2 and nitrogen, with from 1 to 2 per cent. of oxygen. On no account should any CO escape.

High heats produce more gas of a poorer quality, and a smaller quantity of tar of a high specific gravity, and, as the heat is lowered, a smaller quantity of richer gas and a larger quantity of lighter tar are obtained. High heats appear to break up the combinations of hydrogen and carbon, the latter being deposited on the sides of the retort in the form of scurf. When an organic substance, such as bituminous coal, is distilled at a comparatively low temperature, the carbon passes off accompanied by but little hydrogen, liquid compounds of carbon and hydrogen being formed in great abundance, and as a consequence plenty of tar but little gas is obtained, the gas, however, being of a high illuminating power. On gradually increasing the temperature, however, the liquid hydrocarbon decreases, while the gaseous products increase—that is, there is more gas and less tar, the yield of gas increasing as the temperature increases, but the quality at the same time decreases. The effects of temperature on the yield and quality of gas have been very carefully investigated by Mr. L. T. Wright, F.C.S., and in a series of experiments conducted by him the following results were obtained from four portions of the same coal when distilled at temperatures which varied from a dull red heat to the highest temperature obtainable in an iron retort :—

Temperature.	*Cubic feet of gas per ton.*	*Illuminating power (candles).*	*Total candles per ton.*
1. Dull red ...	8,250	20·5	33,950
2. Hotter ..	9,693	17·8	34,510
3. ,, ...	10,821	16·7	36,140
4. Bright orange ...	12,006	15·6	37,460

The temperature of distillation greatly affects the tar produced both as regards quantity and quality, more especially the latter. The quantity of tar obtainable from coal decreases as the distillation temperature increases. When ordinary gas coal is distilled at a temperature of about 800° F. the tar is very thin, consists chiefly of hydrocarbon of the paraffin and olefiant series, and contains but a very small proportion of free carbon; but if the temperature of distillation be raised, say

to about 1,700° F., the tar then becomes thick, and contains much free carbon, while hydrocarbons of the benzine series take the place of the paraffin and olefiant hydrocarbons. With regard to the effect of temperature on the production of ammonia, it would appear that at very low distillation temperatures the yield of ammonia is low, and that a medium temperature produces the greatest amount of the residual, very high temperatures reducing the yield, as shown by Mr. L. T. Wright in the following way :—

Make per ton (cubic feet).	*Yield of NH_3 at per ton.*	*Percentage by weight of coal, as NH_3.*
11,620	7·411	0·331
10,162	7·894	0·352
9,431	7·504	0·335
7,512	6·391	0·285

(NH_3 = *Ammonia.*)

The impurities, carbonic acid, sulphuretted hydrogen, and carbon bisulphide, are considerably increased in quality at high temperatures, and the production of cyanogen, which must now be looked upon as an important residual, is also very considerably augmented when high heats are employed.

The operation of carbonising may now be described. It is conducted somewhat as follows :—The charge of coal is placed in the retorts either with shovels or with scoops, according to the size of the works. In the London district the scoop is employed exclusively. The scoops generally used are semicircular in cross section ; they are made of the length of a "single" retort (shown on pp. 15 and 16), and hold from 1 cwt. to 1½ cwt. of coal. They are furnished with a T-shaped handle, and are raised to the level of the different tiers of retorts by a piece of round bar iron known as a saddle, which is shaped in the centre to the curve of the scoop. The scoop is laid lengthways on the charging floor and filled with coal ; the handle is then raised by one man, while the saddle is placed under the opposite end by two other men, who, one on each side, raise it to the mouth of the retort, when the saddle is removed and the scoop is propelled in and turned over by the man at the handle, who is known as the scoop driver. It is then withdrawn, refilled with coal, and again placed in the retort and overturned, but this time on the opposite side of the retort, so that the coal may lie in a thin even layer.

A retort usually holds 3 cwt. of coal, and is charged in from 40 to 50 seconds. The coal, having been deposited as described, is next backed off the iron mouthpiece by the backing rake, and

the iron door immediately closed, when the operation of gas-making commences, and proceeds on an average for about six hours, at the expiration of which time the coal will have given off all the gas it is capable of yielding and have been converted into coke. Ordinary bituminous coal is generally allowed to remain in the retorts for six hours, and cannel coal for four hours. As no air is allowed to get to the coal, the products obtained are of the same weight as the coal. The hydrogen contained in the coal is driven off by the action of the heat, and passes off, combined with carbon, in various forms. Oxygen as aqueous vapour, nitrogen as ammonia, sulphur as sulphuretted hydrogen and also in the free state, CO_2 (carbon dioxide), CS_2 (bisulphide of carbon), and nitrogen are also given off. Sometimes slaked lime is mixed with the coal in the proportion of $\frac{1}{2}$ cwt. to the ton, for the purpose of acting on the impurities, but it is very trying to the eyes of the stokers, and also spoils the appearance of the coke

The next operation is to draw the charge in the following manner :—The lever on the iron retort lid is first gently loosened, while at the same time a piece of red-hot coke or ignited tarred yarn is placed close to the edge of the lid in order to ignite the gas remaining in the retort the instant the lid is opened. The gas then burns away quietly ; whereas if the precaution mentioned is not taken, and the lid is at once fully opened, cold air rushes in and forms an explosive mixture with the gas, which shakes the retort and is very detrimental to the setting generally. By means of a long iron rake, the coke remaining in the retort is now withdrawn either into iron barrows in which it is wheeled outside the retort house to the coke heap, or, in the case of a stage-floor retort house, it falls through an opening between the front of the setting and the stage, into the coke-hole below, where it is quenched with water. The retort is again ready for charging, but before this is done it is necessary to see that the ascension pipe at the junction with the iron mouthpiece is quite clear by inserting a bent auger into the ascension pipe. With "through" retorts, the operations described are performed simultaneously by separate gangs of three men at each side of the retort setting.

CHAPTER II.

COAL GAS FROM RETORT TO GAS-HOLDER.

The course of the gas from the retort to the outlet of the governor may be thus described :—Leaving the retort, the gas passes, by way of the iron mouthpiece, up the ascension pipe, along the arch or saddle pipe, down the dip pipe into the hydraulic main, bubbling through the liquid contained therein, with the result that it is prevented from returning to the retort. The crude gas as it leaves the retorts carries with it certain substances which it is necessary to remove as soon as practicable; these consist of tarry matters (impure hydrocarbons), carbon dioxide, sulphuretted hydrogen, ammonia, etc., as explained in the previous chapter (p. 24). Now the first operation to which the gas is subjected is that of cooling, which commences immediately it leaves the retort, and in the act of cooling the vapours of various hydrocarbons and water vapour condense into the liquid form, hence the origin of the name condenser. The liquefied hydrocarbon vapours constitute the well-known gas tar, and the condensed water vapour, combining with the ammonia, carbonic acid, sulphuretted hydrogen, etc., present in the crude gas constitutes what is known as virgin ammoniacal liquor.

Fig. 8, p. 26, shows a hydraulic main with connections, A being the ascension pipe leading from the mouthpiece, B the arch saddle-pipe, C the dip pipe, and D the hydraulic main, which is supported on a wrought-iron girder spanning the retort setting, and is provided with a weir valve E for regulating the level of liquor. The object of the hydraulic main is to prevent the gas from passing back to the retort when the doors are opened for drawing and charging, whilst at the same time the gas can freely escape during the time gas-making is proceeding; in other words, the hydraulic main, in conjunction with the dip pipe, forms a self-acting hydraulic seal. This result is obtained by filling the main to a certain level with water and then causing the dip pipe C to dip a short distance (say a couple of inches) into the liquid. The gas, on coming from the retort, has to force its way, therefore,

through this light seal, but, having once passed the seal, it is prevented from returning by reason of the large amount of liquid contained in the hydraulic main, which in practical working is made of such a width in proportion to the area of the dip pipes and their distances apart as to provide sufficient liquid for sealing them against the maximum back pressure that can reach them.

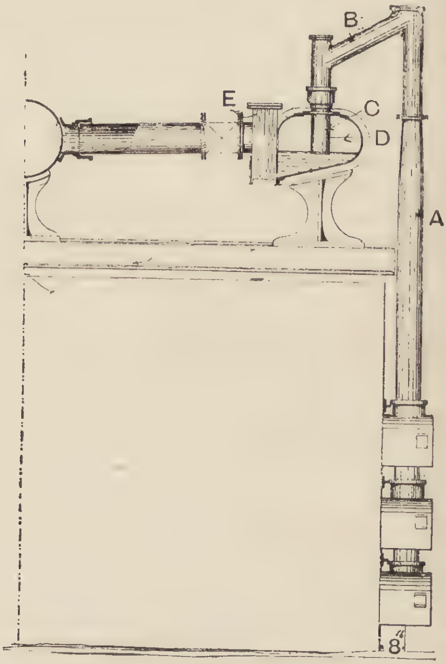


Fig. 8.—Hydraulic Main and Connections.

In Fig. 1, p. 15, the rising pipe is bent over until it looks downward, and enters a trough-shaped pipe of much larger dimensions, termed a hydraulic main, E; this contains water, which is kept at a level rather above the bottom of the entering or dip pipe. This arrangement is made so that when the door of the mouthpiece is opened the gas may not find its way back down the rising pipe. The pipe leading from the retort setting,

shown on Fig. 1, p. 15, and finishing at X, would be joined to the pipe shown on Fig. 10, p. 29, at the point marked X. As soon as the gas enters the hydraulic main a considerable amount of cooling takes place, thus causing a quantity of tarry matters and other condensable substances to be deposited, these finding their way by gravitation to the tar well.

A section of the hydraulic main and dip pipe drawn to a larger scale is shown in Fig. 9, A being the dip pipe, B the interior of the hydraulic main, C the take-off pipe, and D the weir valve. The apparatus is constructed of wrought-iron or mild

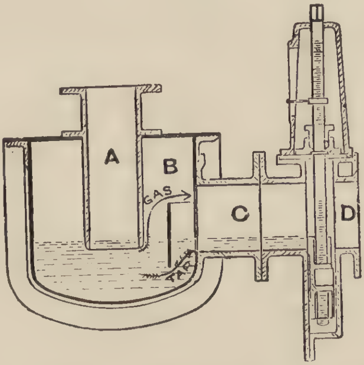


Fig. 9.—Section of Hydraulic Main and Dip Pipe.

steel plate $\frac{5}{16}$ in. thick, attached by 3-in. by 3-in. by $\frac{3}{8}$-in. angle irons. The cover is of cast-iron, as are also the dip pipe and take-off, the former being 5 in. in diameter. The apparatus is 22 in. wide; the object to be kept in view when designing a main being, as explained on the previous page, to seal the dip pipes against back pressure.

In modern gasworks the hydraulic main is divided into separate lengths, corresponding to either one or two settings of retorts, each section being furnished with a separate valve, and connected by a take-off pipe to a gas main on the top of the retort bench, running behind and parallel to the hydraulic main, the take-off pipe which conveys the gas from the hydraulic main to the gas main being provided with a weir valve for regulating the level of the liquid in the main, so as to give the requisite amount of seal as shown in Fig. 9. The dip pipe usually dips for a

distance of about 2 in. in the liquid in the hydraulic main, so that after the gas has once forced this small amount of seal, it is prevented from returning down either its own or other ascension pipes when the mouthpieces are opened during the period when the retorts are drawn and charged. Leaving the hydraulic main at a temperature of about 150° F., the gas next enters the condensing plant, where its temperature is reduced to about 60° F., and the remainder of the tarry bodies are eliminated, together with considerable quantities of weak ammoniacal liquor.

The chief impurities in crude coal gas, for which qualitative tests are required—namely, ammonia (NH_3), sulphuretted hydrogen (SH_2), and carbon dioxide, commonly known as carbonic acid (CO_2)—are detected by the following methods:—The presence of ammonia is shown by its action on a moistened turmeric paper or a reddened litmus paper. Turmeric papers are prepared by soaking strips of filter or blotting paper in an alcoholic solution of turmeric, made by digesting powdered turmeric root in the liquid. They are allowed to dry, are cut into strips, and are then ready for use, but must be kept in a dark place. Turmeric papers thus prepared are of a full yellow colour, which in the presence of ammonia changes to a brownish tint, and sometimes to a deep crimson colour, according to the quantity of ammonia present. The papers should be moistened before use. A more sensitive test for ammonia is that of the reddened litmus paper (glazed), which turns blue under the action of ammonia.

Sulphuretted hydrogen is detected by causing a current of gas to play on a piece of white paper previously dipped in a solution of acetate of lead or nitrate of silver. The presence of sulphuretted hydrogen is shown by the paper changing to a brownish black colour, due to the formation of lead or silver sulphide, according to the reagent employed. Carbonic acid is detected by causing a current of gas to bubble into lime or baryta water, a white precipitate of calcium or barium carbonate being formed if CO_2 is present in the gas. Lime water is the solution most commonly employed, and is prepared for use by placing about 4 oz. of caustic lime in a quart bottle, filling up with distilled water to dissolve the lime, and shaking the bottle occasionally to assist the operation. When the water has taken up as much of the lime as it is capable of dissolving, the excess of lime is allowed to settle, and the clear liquid is transferred

to another bottle, which must always be kept tightly corked to prevent the access of CO_2 from the atmosphere. In order to make a test, about 1 oz. of the lime water is placed in a test tube or small bottle, and the gas bubbled slowly through it by means of a glass tube having a very fine opening, this latter tube being connected to the gas supply by a piece of indiarubber tubing. In practice, if a precipitate does not form within the space of three minutes, it is assumed that the gas is free from CO_2. If sulphuretted hydrogen is also present in the gas being tested, it will be necessary to interpose a small oxide purifier, so as to prevent any sulphuretted hydrogen entering the lime water, since the presence of the latter gas would vitiate the test.

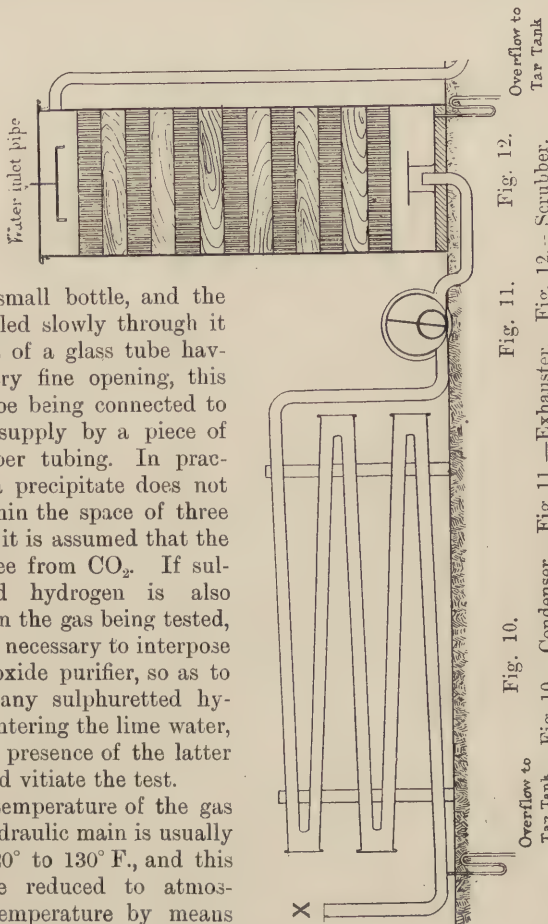


Fig. 10. Fig. 11. Fig. 12.

Fig. 10.—Condenser. Fig. 11.—Exhauster. Fig. 12.—Scrubber.

The temperature of the gas in the hydraulic main is usually about 120° to 130° F., and this must be reduced to atmospheric temperature by means of condensers (Fig. 10). These are of many kinds, but may be divided into two classes—namely, air condensers and water condensers.

The gas is thus brought into a suitable condition for the after process of purification. The tarry bodies and other substances thus eliminated would, if not removed at an early stage in the manufacture, clog up the purifying apparatus. Condensation commences immediately the gas leaves the retorts, with the result that water vapour and the vapours of various hydro-carbons condense into liquids, producing what is commonly known as tar, and a weak, impure solution of ammonia, known as virgin ammoniacal liquor, due to the absorption of ammonia, sulphuretted hydrogen, carbonic acid, and hydrocyanic acid, by the liquefied aqueous vapour. These liquids collect in the hydraulic main, where a very considerable amount of cooling takes place, since, by the time the gas reaches the outlet of the hydraulic main, it will have deposited from one-third to one-half of its condensable constituents, and have been reduced in temperature from, say, 2000° F. in the retort to from 150° F. to 110° F. at the outlet of the hydraulic main. The remaining portion of the work of condensation is next effected in the condenser proper, the apparatus being usually placed between the retort house and the exhauster. In some works the gas passes through a length of main running round the retort house, and known as the foul main, before it enters the condensers. The air condensers embrace the vertical, the annular, the horizontal, and the battery, while the principal water condensers are those of Morris and Cutler, and Livesey. The action of these different forms of air condensers is practically the same, the principle on which they act being that they transmit the heat from the gas passing through them to the external air in contact with their outer surface, with the result that the gas and vapours are cooled, and the condensable vapours deposited.

As a familiar instance of the process of air condensation, take the simplest form of the apparatus, namely, the ordinary vertical condenser, which consists of a series of vertical pipes attached to a cast-iron chest or receiver at the bottom, and connected in pairs by semicircular bends at the top. The cast-iron chest is provided with a series of mid-feathers, which dip to a certain depth in liquid, forming a seal, so that the gas is caused to pass up one pipe and down the next right along the series; the condensed products are deposited in the chest, whence they flow by a sealed overflow to the tar well. The battery condenser possesses one or two features that render it a more efficient apparatus than the

other types of air condensers—namely, that the gas is subjected to more friction than is possible with the small amount of "skin" contact which it undergoes in the ordinary form of apparatus; and as a certain proportion of the tar exists in the form of little vesicles or bubbles, it is necessary, before all the tar can be eliminated from the gas, that they should be broken up by some means such as the battery condenser affords. The apparatus consists of an oblong vessel of from 1 ft. to 2 ft. wide, 12 ft. to 18 ft. high, and of varying length. It is divided in the inside by a series of mid-feathers placed at distances apart equal to the width of the apparatus; the mid-feathers extend to within a few inches of the top and bottom of the chest alternately, the gas passing from the inlet up and down each division to the outlet. In order to increase its condensing power, a series of small tubes of about 2 in. in diameter pass from side to side of the vessel. These tubes are open to the atmosphere, so that the air is capable of circulating freely through them; this helps to cool the gas, and further serves to break up the tarry particles as before described. The water condenser is regarded by many eminent authorities upon gas manufacture as being much superior to the air condenser, inasmuch as it admits of easy regulation, while the cooling agent (water) is much more powerful than air, since water has a far greater power of absorbing heat than air has. As a type of the water condenser, the Livesey may be mentioned. In the Livesey condenser the gas passes through a series of pipes placed in a tank of water divided into separate channels, with the water flowing in an opposite direction from the gas, the cool water entering the apparatus at the gas outlet end, and getting gradually warmer as it approaches the gas inlet. According to the amount of water admitted, so will the temperature of the gas be raised or lowered.

On leaving the condensers, the gas is put through the exhauster (Fig. 11, p. 29), which is a kind of rotary fan or pump employed in order to overcome the resistance offered to the passage of the gas on its way from the retorts to the gas-holder. The whole of the apparatus through which the gas has to pass offers a certain amount of resistance; the seal of the dip pipes, the friction of the condensers, the seal of the washer, the filling material of the scrubber, the rotating bundles of the washer-scrubber, the materials in the purifier, the measuring wheel of the meter, and finally the weight of the gas-holder, all

exercise an amount of back pressure as it is termed, and the combined resistance of the whole apparatus is sometimes very great, so that if means were not taken to overcome this, the whole of the gas would not find its way to the gas-holder, but a great portion of it would pass through the porous walls of the retort and be burnt in the furnace. The exhauster overcomes or neutralises the resistance of the seal of the hydraulic main, and causes a partial vacuum in all the pipes in the retort-house and condenser. On the outlet of the exhauster, however, a pressure is given sometimes equal to 42 in. head of water, or a little under 2 lb. per square inch; this is required to force the gas through the remaining purifying apparatus, and to fill up the holders. Another reason for employing the exhauster is that its use lessens the deposition of carbon on the walls of the retort. When gas passes over hot surfaces under such a pressure as results when an exhauster is not employed, it is partially decomposed, and the carbon thus set free settles on the retort in the familiar form of carbon or scurf, which takes up retort space and entails a waste of fuel, in addition to impoverishing the quality of the gas. The exhauster is usually turned either directly from the axle of a steam engine, or, in some small works, by a gas engine, the tarry matters remaining in the gas serving as lubricants to the fans.

The next step is to arrest the remaining tarry vapours and some of the ammoniacal liquor. This is done by means of tar-extractors or washers; in these the gas is made to pass through inverted troughs with serrated edges just below the level of weak ammoniacal liquor, which causes the latter to bubble up and expose a large surface to the gas. The reason of the use of weak ammoniacal liquor, instead of clean water, is the affinity it has for carbon dioxide, sulphuretted hydrogen, and other sulphur compounds, and the fact that the liquor is brought up to the requisite commercial strength.

Scrubbers are of many kinds, but in all the patterns the gas is made to pass in finely divided streams between wetted surfaces. This is done by the scrubber shown at Fig. 12, p. 29, which is a cylindrical vessel on end, in which layers of thin boards are placed on edge with small spaces between, and are set to cross one another. Water is distributed from the top over the boards, and trickles down their sides; while the gas, entering at the bottom, is broken up into finely divided streams, and thus a large surface is exposed to the wetted faces of the boards. An

overflow, suitably trapped, is provided at the bottom to carry off the ammoniacal liquor to wells generally built underground.

The most common form of scrubber is that known as the tower, so called because it is frequently of a considerable height. A pair of such scrubbers is shown in Fig. 13. They are cylindrical in shape, and are constructed of cast-iron plates, with faced or caulked flanges, the plates varying from 6 ft. to 20 ft. in diameter; they are put together in sections, attaining a height of from 20 ft. to 80 ft. The plates are from ⅝ in. to 1 in. in thickness, with mouldings as shown. Strong cast-iron brackets are fixed at the

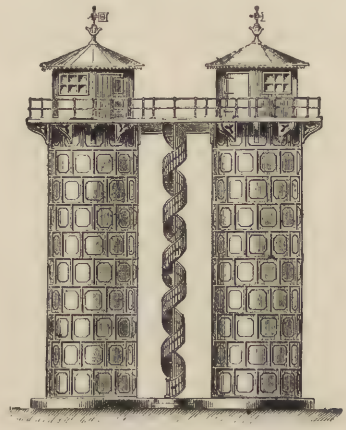


Fig. 13.—Pair of Tower Scrubbers.

top for the purpose of supporting a circular gallery, which connects the scrubbers together, two or more being usually so connected. Each scrubber is provided with a penthouse, which contains the water-distributing machinery, to which ready access is obtained by a spiral staircase. In the interior of the scrubber is a series of iron grids, on which are placed various materials, usually coke, but sometimes thin boards set on edge. The gas enters the scrubber at the bottom, and leaves it at the top through a pipe which occupies the centre of the apparatus. The action of the apparatus is as follows:—The gas enters at the bottom, as previously stated, and a fine stream of water or ammoniacal liquor descends from the top, and in its course, having to descend through the material in the vessel, thoroughly

wets it, with the result that the ascending gas is deprived of its ammonia. The resulting ammoniacal liquor collects at the bottom and passes away through a seal pipe sealed in a seal pot to the liquor well. The usual practice is to work two scrubbers in series, the first one being supplied with weak liquor from the hydraulic main and condensers, and the liquor resulting from the other scrubber, which is supplied with clean water. By making scrubbers in this way the liquor is concentrated and the absorptive power of virgin ammoniacal liquor for the impurities $SH_2 + CO_2$ is fully utilised, while the gas, coming in contact finally with clean water, is rendered quite free from ammonia.

Another type of scrubber is shown in section by Fig. 14, and is called (after the inventor, Mr. George Anderson) Anderson's brush scrubber. The apparatus consists of a rectangular cast-iron vessel, 4 ft. by 10 ft. inside, and about 24 ft. high, standing upon end, divided into a series of shallow pans or tanks containing ammoniacal liquor. These tanks are arranged one above the other, each one being provided with a drum, which revolves within the tank, the circumference of the drum being fitted with a brush of whalebone or other suitable material. The brush drums are made to exactly fit their respective chambers, while their lower side dips into the liquor contained in the tanks. Motion is given to the drums from the outside by means of a vertical shaft and gearing actuated by a line-shaft and worm-wheel, and each drum revolves in the contrary direction to that in which the gas is passing. Hand-holes are provided in the side of the vessel for the examination or replacement of the brushes as they wear out. The apparatus is usually combined with one of Anderson's washers, and stands on the last-named apparatus. The direction taken by the gas is shown by the arrows—on first entering the washer at A (Fig. 14), it comes in contact with the serrated edges on the underside of the first horizontal plate ; it rises at the end and returns among similar serrations in the plate depending from the cover, and thence passes up into the first compartment containing the brushes. The washer is charged with weak ammoniacal liquor, and the passage of the gas through the liquor causes an increase of pressure at the inlet as compared with the outlet end, so that, according to the pressure at which it is desired to work, the teeth at the inlet end are made proportionately longer, in order that they may be parallel to the inclined plane which the passage of the gas causes the water to assume.

Means are provided for raising or lowering the water line, in order to raise or lower the pressure according to requirements.

The gas on entering the scrubber proper passes about two-thirds round the lower brush and thence out at the opposite end to that at which it entered, and similarly with each of the brushes, until finally it escapes at the outlet B (Fig. 14). The flat pipe communicating with the several brush compartments extends nearly the whole length of the brush, and is cast on a portion of the outer case, with the object of ensuring an equal distribution of gas. Each compartment contains liquid to the height of the pipe that brings the gas from the compartment below. Pure water is run into the upper compartment, ultimately finding its way down the pipes up which the gas passes, until it arrives in the washer at the bottom. The shafts of the several brushes are provided with driving-gear, so that the brushes move in opposite directions, and always in the reverse direction to that in which the gas is passing in any particular compartment. The efficiency of the machine depends to a great extent on the speed at which the brushes revolve, but in practical working from three to five revolutions per minute will ensure the removal of all the NH_3 from the quantity of

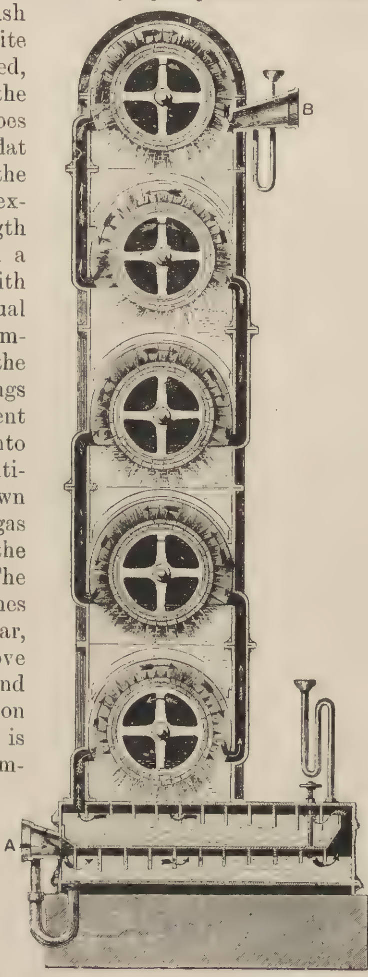


Fig. 14.—Anderson's Scrubber and Washer.

gas for which the machine is designed. The brushes by revolving with their lower side dipping in liquid lift a quantity of the latter in their fibres, through which the gas has to pass, leaving a portion of its impurities, which is washed off by the continuous revolution of the brush. The liquid in the several compartments is therefore of different strengths, that at the bottom being the strongest, whilst pure water is found at the top. When purifying gas made by carbonising Newcastle coal, from 10 to 12 gallons of pure water are run in at the top of the apparatus for every ton of coal carbonised, and the weak ammoniacal liquor from the hydraulic main is poured into the sealed pipe in the top of the washer. The merits that the inventor claims for this over other types of scrubber are, that for the same quantity

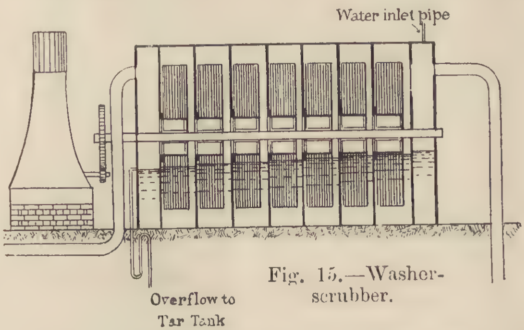


Fig. 15.—Washer-scrubber.

of gas to be purified the vessel can be made much smaller, that the distance through which the gas has to travel is about double for the same height, and that there is no risk of the gas failing to come into intimate contact with the scrubbing liquid, the result being the complete removal of the whole of the ammonia.

Another form of scrubber that has been very largely adopted is called a "washer-scrubber" (Fig. 15). This is also a cylindrical cast-iron vessel; it is fixed horizontally, and divided into sections, in which a series of discs or chambers containing wooden balls, or other filling, is made to revolve slowly on a central shaft. The liquid is at a different height in each chamber, but averages about one-third up the discs, which are wetted as they rise from it, whilst the gas passes between them and gives up its ammonia and a portion of its other deleterious compounds. The clean water entering at one end meets the gas that enters at the other,

through a space in the middle of the discs, and increases in strength as it flows from one chamber to another, until it reaches the desired amount, generally known as 10 oz. or 12 oz. ammoniacal liquor; the gas passes on, and, meeting the cleaner water, gives up in each compartment a portion of the ammonia, until the latter is all eliminated.

The bulk of the carbon dioxide, sulphuretted hydrogen, and bisulphide of carbon, however, still remains in the gas, and must be removed. This is most effectually done by what are called purifiers (Fig. 16). These are usually rectangular boxes containing several layers of wooden grids, on which the purifying material is laid, and through which the gas has to pass from the inlet at the bottom to the outlet at the top. In London, where the law requires that the gas shall be in a high degree of purity, no sulphuretted hydrogen whatever is allowed to be in the gas. Of other sulphur compounds not more than 17 grains in 100 cubic feet of gas is allowed in summer, and not more than 22 grains in 100 cubic feet of gas in winter, while the maximum amount of ammonia (NH_3) must not exceed 4 grains per 100 cubic feet. It is therefore necessary to carry the purification much further than is considered sufficient in other parts of the country. Whether this great refinement is necessary need perhaps hardly be discussed here; suffice it to say that the cost of removing the impurities to such an extent is considerably more to the consumer than would be the case if only the same portion had to be taken away that is sufficient in the country. In some country works only lime is

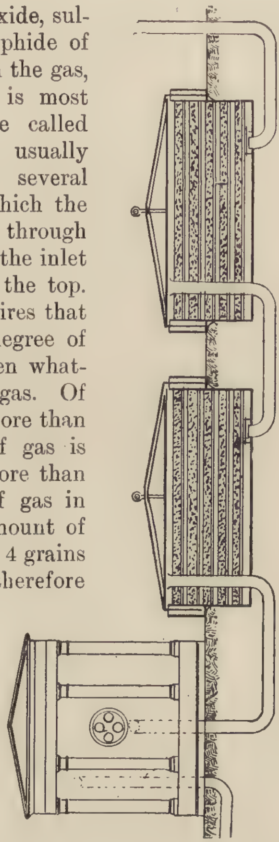


Fig. 16.

Fig. 17.

Fig. 16.—Purifiers. Fig. 17.—Station Meter.

used for purification, and in others oxide of iron only is used. Each of these can be made to remove what for all practical purposes it is necessary to eliminate; but where more than this has to be done, it is usual to employ a combination of the two, arranged in what may at first sight appear to be a rather peculiar manner. To work this system successfully, eight purifiers are required. In the first two, hydrated lime is used, and the gas in passing through them gives up all the CO_2 that it contains; it then passes on to the next two vessels, which are filled with hydrated oxide of iron, this material having a great affinity for sulphuretted hydrogen, which it effectually removes. The gas then passes through two more vessels containing lime, and it is here that the peculiarity just mentioned occurs.

Hydrated oxide of calcium (lime), which has great affinity for CO_2 (carbon dioxide), is useless for removing the sulphur compounds, principally in the form of bisulphide of carbon; but hydrated oxide of calcium, which has been sulphided by means of sulphuretted hydrogen, has this power, and therefore, in preparing a set of purifiers for use, the gas is passed first through the two purifiers containing the lime (CaO) for the removal of the CO_2, and then through the two others, which also contain lime. These latter take up and assimilate with themselves the H_2S, forming a sulphide of lime, which is then used in its proper turn to remove the CS_2; but in doing so a certain quantity of sulphuretted hydrogen is given off from the sulphided lime, and to prevent this passing along with the gas two check purifiers are used, filled with oxide of iron, or in some cases Weldon mud—a substance containing a large proportion of oxide of manganese. Below is a diagram explaining this. Gas contains CO_2 H_2S, CS_2.

Purifier containing lime removes CO_2 and some H_2S.	Purifier containing iron oxide removes remainder of H_2S.	Purifier containing sulphided lime removes CS_2.	Purifier containing iron oxide or Weldon mud removes H_2S.
Gas contains H_2S, CS_2	Gas contains CS_2.	Gas contains small quantity H_2S from lime.	Gas clean.

All that now remains to be done is for the gas to be measured, which is done in an apparatus which is in all respects similar to the wet meter found in many houses, but, of course, on a very much larger scale, as shown at Fig. 17, p. 37. An ordinary wet meter is a drum of a known size, with partitions so arranged that while the gas is entering one compartment it is being passed out from that portion previously filled, a direct communication between inlet and outlet never being possible. The revolution of the drum causes certain wheels to turn, and pointers affixed on it to indicate the number of revolutions made, thus showing the quantity of gas passed through.

The station meter is employed to measure the gas made on a gasworks, so as to enable the engineer to see that he is getting the proper amount of gas from his coal ; it also serves to tell the amount of leakage or unaccounted-for gas. The station governor is employed for the purpose of controlling the pressure under which gas is supplied at the works to the amount necessary for the proper supply of the district and no more. The station meter is shown in section in Fig. 18, p. 40, and consists of a round or rectangular cast-iron outer case containing a cylindrical vessel of tinned iron known as the drum, which revolves on a horizontal shaft resting on suitable bearings. The drum is immersed to a certain height in water contained in the outer case. The drum varies in size according to the capacity of the meter, and is divided by partitions into four longitudinal compartments arranged somewhat after the fashion of the four blades of an Archimedean screw. The inlet-end or unmeasured gas is isolated from the outlet or measured gas, by the contrivance known as the "spout and bottom cover," shown at V. Owing to the manner in which the partitions that form the compartments or chambers are arranged, there is not a clear way through the drum, since the opening at one end of a measuring chamber is above the water line at the same time that the corresponding opening at the other end is below it, so that two of the compartments are constantly above the water-line, the one filling with gas and the other discharging. The openings at the ends of the chambers through which the gas passes are known as hoods. The action of the apparatus is briefly as follows :—The gas enters at W through the spout above the level of the water, and enters one of the measuring chambers, causing it to revolve. As soon as the chamber is filled with gas, its inlet has passed

beneath the water level by the revolution of the drum, with the result that the gas is sealed up, while the inlet of the next chamber rises at the same time above the water level, and thus allows gas to enter. As soon as the inlet to each chamber is sealed, a corresponding outlet slit that opens into the space between the drum and the outer case is unsealed, and water entering by the inlet forces the gas through the slit to the meter outlet. Each chamber in rotation as it fills with gas turns the drum round a quarter of a revolution, and expels the gas from the chamber that has preceded it. The cubical space in each

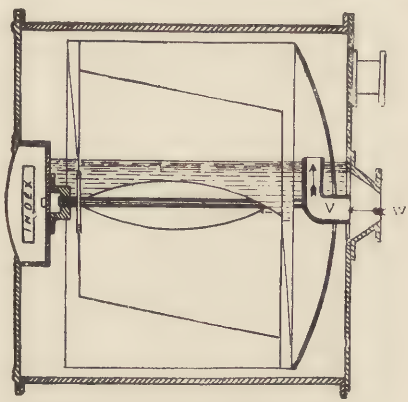


Fig. 18.—Section of Station Meter.

chamber when out of the water and full of gas is known. Four times this space represents the total capacity of the drum, or the contents for one revolution. The shaft of the drum is connected to a train of wheels provided with pointers traversing the meter dials, by which the number of revolutions made by the drum is recorded and the amount of gas passed is registered. In order to maintain the water in the meter at the proper level, a small continuous supply of water is constantly admitted, a syphon overflow pipe being provided to take off any excess.

The gas, not being required in all cases immediately it is made, is stored in what are commonly known as gasometers, but which are more correctly termed gas-holders (Fig. 19). These are vessels made of thin sheet-iron, free to travel up or down in a vertical direction as they are filled or emptied. They are worked

n circular tanks, which, in small works, are the same depth as the gas-holder is high ; but in large works the gas-holder is made in two or more lengths, each smaller than the other, so that when down they may telescope into one another. To prevent the gas escaping, what are known as a "cup" and "grip" are made, the one at the bottom of each "lift," as each length is called, and the other at the top of the next outer lift. The cup is formed so that the lower end of the lift is bent outwards and up a certain height all round, thus making it a concentric vessel, which, as it rises from the water in the tank, takes up with it sufficient of the

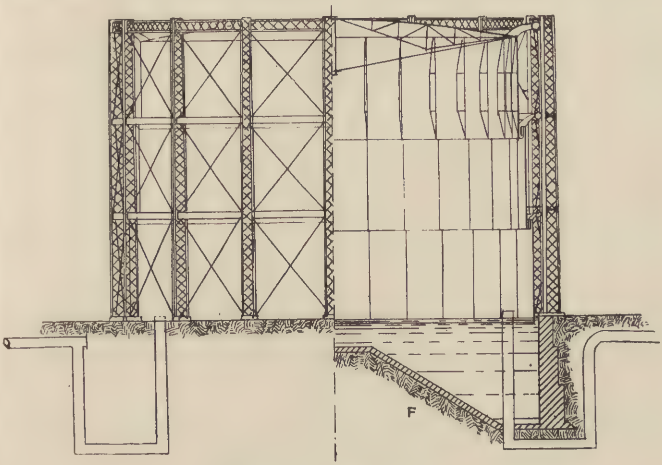


Fig. 19.—Gas-holder.

latter to fill the cup. At the same time it engages with or catches the grip of the next outer lift, which is made so that the upper end is bent outward and downwards about the same depth as the cup, thus, owing to the sealing of the grip in the water in the cup, preventing the passage of the gas from the gas-holder to the outer atmosphere.

Most gas-holder tanks of any size are made with what is known as a dumpling in the middle ; this is shown at F (Fig. 19). It is merely a certain quantity of the ground left in when the remainder was being excavated, so as to save work and to lessen the quantity of water required. Some also are made with concentric tanks, space for the lifts to fit in only being allowed

Others, again, have cast-iron tanks when the ground is much saturated, and these are generally placed above ground.

Fig. 20 gives a sectional elevation of an untrussed gas-holder and puddle tank. The holder is telescopic and in three lifts ; the tank is 230 ft. in diameter by 50 ft. 6 in. deep from bearing stones to top of coping, and is built of brick set in Portland cement mortar in the proportion of one part of cement to two of sand. The sides and bottom of the tank are both puddled to the thickness of the puddle behind, the side walls being 24 in., and on the bottom 15 in. The holder when not inflated rests on a timber framing, as shown in the illustration, the size of the timbers being 12 in. by 12 in. for the uprights and diagonals, and 13 in. by 7 in. for the curved portion of the framing. The outer lift is 226 ft. in diameter and 50 ft. deep ; middle lift, 223 ft. diameter and 50 ft. 3 in. deep ; inner lift, 220 ft. diameter and 50 ft. 6 in. deep. The crown has a rise of 15 ft., and is untrussed. The curb is formed of $\frac{3}{4}$-in. plates, bent to a radius of 2 ft. 3 in., and is strengthened by a plate-girder and gusset stays. The standards are of the lattice-girder type, and are braced together by three rows of girders, as shown, and by diagonal flat bars. The thickness of the roof sheets is as follows :—Outer row, forming part of curb, $\frac{3}{4}$ in. thick, of mild steel plates, 3 ft. wide ; next row, No. 7 B.W.G., then follows another row of No. 9 B.W.G., the remainder being all of No. 10 B.W.G., the latter being riveted with $\frac{5}{16}$-in. rivets of 1-in. pitch. The No. 7 B.W.G. sheets are riveted to the $\frac{3}{4}$-in. curb, plated by $\frac{3}{4}$-in. rivets $2\frac{1}{2}$-in. pitch. The side sheets are of No. 11 B.W.G., secured to each other with $\frac{5}{16}$-in. rivets, 1-in. pitch, lap of sheets $1\frac{1}{4}$ in. ; the bottom and the top row of the sheets in the outer lift are $\frac{1}{4}$ in. and $\frac{3}{16}$ in. thick respectively, in the middle lift $\frac{3}{16}$ in., and in the top lift $\frac{3}{16}$ in. and $\frac{1}{4}$ in. respectively, being riveted to the other sheeting with $\frac{3}{8}$-in. rivets, $1\frac{1}{4}$-in. pitch, $\frac{3}{8}$-in. lap. Inlet and outlet pipes, 36 in. diameter.

A gas-holder throws a pressure varying acccording to its weight and the area covered by it, but the pressure is nearly always more than is required to be sent out on the district, and, if delivered, would cause escapes at many of the fittings in the consumers' houses otherwise sufficiently sound. A governor is therefore used ; it is in reality a small gas-holder, which rises and falls according to the pressure of gas on the district, opening or closing a valve, as may be desired, by means of a cone.

The station governor in its simplest form consists of a small

cast-iron tank, which is filled to a certain height with water, and through the bottom of which the gas from the gas-holder enters by a pipe provided at the top with a flanged seating. Surrounding

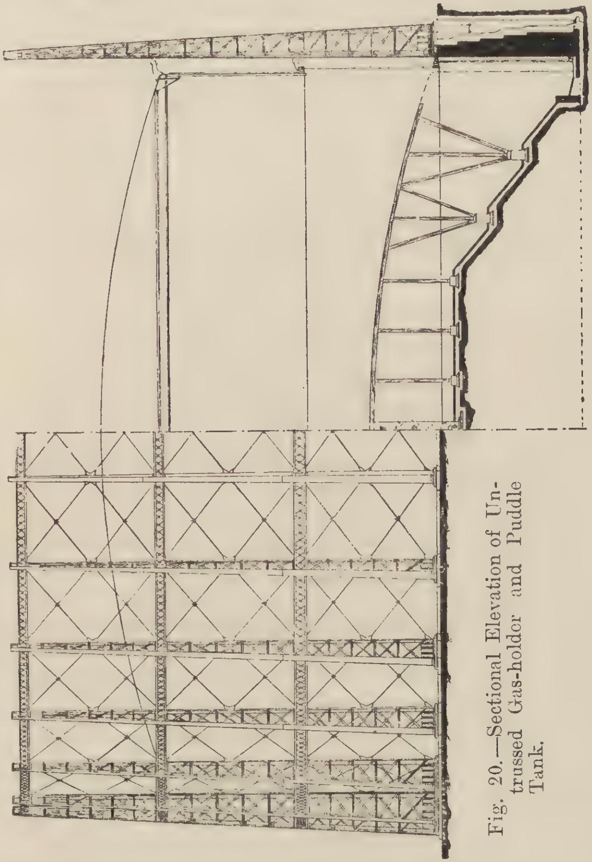


Fig. 20.—Sectional Elevation of Untrussed Gas-holder and Puddle Tank.

this inlet pipe is the outlet pipe, whose open end projects some distance above the level of the water in the tank, the gas passing to the street mains by way of the annular space between the two pipes. The governor usually employed is shown in Fig. 21, p. 44, and consists of a small cast-iron tank x, which is filled to a certain

height with water. Firmly floating in the tank is a tinned iron gas-holder Y, having suspended from its crown a parabolic plug Z. The gas inlet pipe is in the centre of the tank, and is provided at the top with a flanged seating that exactly fits the parabolic plug. The outlet pipe is concentric to the inlet pipe, and rises some distance above the level of the water in the tank. The gas-holder is balanced by means of an air chamber placed inside the vessel round its lower curb, so that when the water in the tank is at its proper level the holder rises, carrying with it the suspended para-

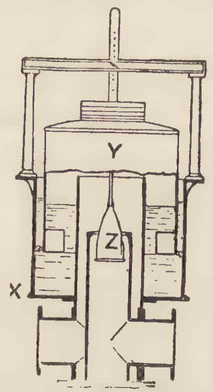


Fig. 21.—Station Meter Governor.

bolic plug; and, supposing all the weights on the top of the holder to be removed, the holder would ascend to its full limit, carrying with it the suspended plug, which would ultimately fill the orifice of the inlet pipe and consequently shut off the gas supply, reducing the pressure in the shut mains to nil. Since a certain pressure is always required, however, iron or leaden weights are placed on the crown of the holder, equivalent to the pressure needed to supply the district, so that the holder only ascends a certain distance, while the suspended plug fills the orifice in the inlet pipe to such an extent as will allow sufficient gas to pass and give the outlet pressure required, which is rigidly maintained, no matter what variations may take place in the amount of gas consumed in the district; for in the event, say, of a sudden demand on the street mains owing to a fog, or to other causes that would involve an increased consumption of gas, the pressure in the

mains would be reduced, and as the governor holder communicates by means of the outlet pipe with the shut mains, this reduced pressure would cause the holder to descend ; in doing so, the parabolic plug would also descend, and thereby increase the valve opening and allow more gas to pass through, although not in any way affecting the initial pressure, but only maintaining it at a constant quantity. Similarly, should the consumption in the district slacken, the gas-holder would rise and lift up the suspended plug higher into its seating, thus reducing the gas-way and equalising the pressure. Of course, the governor is not intended to control the initial pressure which is required for supplying the district ; this is regulated by adding or taking off weights from the crown of the gas-holder.

CHAPTER III.

GAS SUPPLY FROM GAS-HOLDER TO DOMESTIC METER.

Gas-fitting is not an exact science in which, for the guidance of beginners, a complete code of undeviating rules and regulations can be laid down. A gas-fitter requires to be something more than a mere mechanic. He must be not only able and willing to employ his hands in various forms of skilled labour, but must also make use of his wits and exercise his ingenuity. In these days of competition, brainwork counts for more than skilled labour; and the gas-fitter who can point out correctly and convincingly the most effective and, at the same time, the most hygienic methods of lighting a building is much more likely to succeed in business than the man whose ability is purely mechanical.

Gas, even though an old and well-tried servant of the public, has, for some reason or other not quite clear, been unfairly disparaged, every conceivable argument against it being eagerly and incessantly advanced. This state of affairs is mainly owing, not to the shortcomings of the gas as an illuminant, but rather to the ignorance of its advocates. The intelligent workman must be able to prove by argument and to demonstrate in practice that the case against gas-- particularly with respect to the allegations as to its unhealthiness—has been grossly exaggerated.

A good gas-fitter should not only be thoroughly acquainted with the minutest details of his own trade, but it is necessary that he should also possess a sufficient general knowledge of certain other trades, so that he may be enabled to meet the requirements or to direct the operations of those workmen with whom his business brings him in most frequent and most direct contact.

Houses differ so much in shape and size that, with respect to fitting them with gas, only general principles can be advanced. In all cases the number of lights to be fed and the distance from the supply govern the size of the pipes used. The pipes are of

three kinds—wrought-iron barrel, lead, and compo. One of the advantages of iron is that nails cannot be knocked into it when it is buried in a wall; but it is much more difficult, and takes considerably longer, to fit up a house with iron pipe than with compo., owing to the fact that with the former material bends have to be fitted, and the pipes must be cut to the exact length and threads screwed on. Lead pipe is generally used only for the connections to the meters.

In laying mains, great care should be taken that all the joints are sound and well made, in accordance with the instructions given in this chapter, and that the pipes are of good quality. The mains should be tested under high pressure, and when tapped with a hammer should ring; they should be quite free from sand-holes, air-holes, scabs, and blisters, and should be of cast iron, which can be easily tapped and drilled. Where it happens unavoidably that the pipes are laid in ground containing ashes or any chemical refuse, they must be properly protected either with clay or asphalt. Clay should never be put only under the pipe, as it then stops the water and keeps the pipe wet. The durability of mains depends greatly on the nature of the soil in which they are laid, clay being the best subsoil for this purpose, and ground containing ashes, slag, and clinker the worst.

It is necessary, therefore, to note carefully the description of soil in which the pipes are to be laid, and if it is of an injurious character, to imbed the pipes carefully in a good common soil, or to puddle them round completely with clay, protecting especially the upper side with a thick covering of the material. The pipes should have a covering of at least 2 ft. of soil over them in order to protect them from climatic influences and from heavy traffic such as steam rollers, etc. The excavation to receive the pipes should be of the least width practicable, so that the labour of filling in may not be excessive. If the bottom of the trench on which the pipes rest is not already even and firm, it should be thoroughly consolidated by pressing. The soil should be scooped out at the various points in the trench where the sockets come, so that the body of the pipe may be laid solid throughout its entire length.

Another subject for early consideration is the size of main required for delivering a specified quantity of gas. In calculating the size for a gas main capable of delivering a specified

quantity of gas through a given length of main, the following formula is employed:—

$$d = \sqrt[5]{\frac{2\,Q\,s\,l}{(1350)^2 h}}, \text{ where}$$

d = diameter of pipe in inches.
Q = quantity of gas in cubic feet per hour.
l = length of pipe in yards.
h = pressure in inches of water.
s = specific gravity of gas, air being 1.

The above formula can easily be calculated by the aid of a table of logarithms. Thus, log. $d = \frac{1}{5}$ (2 log. Q + log. s + log. l − 2 log. 1350 + log. h). Suppose, for example (to take an actual case), that a gas main is required for a building of somewhat straggling construction, and situated at about 500 ft. from the company's main, about 900 burners being required, some in groups of two or three. The burners may be taken as burning 5 cub. ft. per hour each; then the nearest size of main required would be 4 in. Supposing the reader to be unacquainted with the use of logarithms, the following formula, where the size of main is assumed in the first instance, will probably be found more useful:—

$$Q = 1350\,d^2\sqrt{\frac{h\,d}{s\,l}}$$

that is, multiply the pressure in inches of water by the diameter of the pipe also in inches. Divide this product by the specific gravity of the gas multiplied by the length of the pipe in yards. Then find the square root of the quotient and multiply this by the constant 1,350 and the square of the diameter of the pipe in inches, and the result will give the number of cubic feet discharged per hour. Using this formula to check the result obtained by the one first given, the specific gravity of the gas is assumed to be ·4, and the pressure 1 in. or ten-tenths. Then the query is, to find the number of cubic feet of gas of the specific gravity ·4 capable of being delivered in one hour through a main 4 in. in diameter and 500 ft. or 166 yds. long under a pressure of 1-in. head of water. Then, $h\,d = 4 \times 1 = 4$, while $d^2 = 4 \times 4 = 16$, and $\frac{h\,d}{s\,l} = \frac{4}{\cdot 4 \times 166} = \cdot 0602$, the sq. root being ·2453. Therefore $1350\,d^2\sqrt{\frac{h\,d}{s\,l}} = 1350 \times 16 \times \cdot 2453 = 5298$, which shows that the main would be amply large; the next

lower size (3 in.) would be too small. It is necessary to note that in the case of small service pipes the actual discharge is less than the calculated quantity, so that it is necessary to increase the diameter of the pipe by one-third if of lead and by one-half if of wrought iron.

Yet another important subject for consideration in laying mains is the way in which ordinary gas lighting is affected by difference of level between the gasworks and the houses supplied. The specific gravity of coal gas varies with its richness or illuminating power, but in all cases it is less than that of the atmosphere. If one portion of a town is below and another above the works, the gas will rise to the higher parts by reason of its lightness, but will have to be forced to the lower parts by the weight of the gas-holder. In other words, for a pressure of $\frac{6}{10}$ or $\frac{8}{10}$ in a valley the mains must be so charged as to exert double or more, or say $\frac{12}{10}$ to $\frac{30}{10}$ in higher places. If a high building is supplied from one rising main only, the gas will so rise to the upper floors as to necessitate the use there of burners different from those on the lower floors; or, alternatively, gas pressure governors may be fixed on the various floors. The gas should escape at a certain pressure to form a solid flame, the burners being selected in accordance therewith. If the gas escapes feebly, a flickering flame will be the result, and a quantity of smoke will be given off.

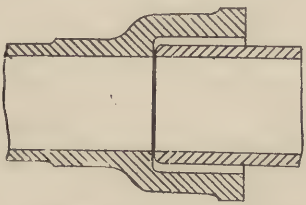


Fig. 22.—Socket and Spigot Joint.

The general method of making joints in gas mains is illustrated by the section shown by Fig. 22. It is called the socket and spigot joint, and is sometimes known as the open joint system. In making a joint of this description, the spigot of the pipe about to be laid is placed in the socket of the pipe already laid, leaving an annular space between the spigot and the socket. The inner portion of the annular space is then filled with twine gasket to about half the depth of the socket, the gasket being driven well in with the caulking tool. The outside face of the joint is then tightly closed by means of a belt of plastic clay, which completely encircles the pipe and presses up against the

face of the socket, leaving an opening known as the lip on the upper side of the pipe. Through this opening molten lead is poured, filling up the remaining space between the gasket and the clay, the excess of lead flowing over at the lip. The clay is then removed, and the joint when cold is set up, as it is termed, with a blunt caulking tool and hammer, so that the ring of lead

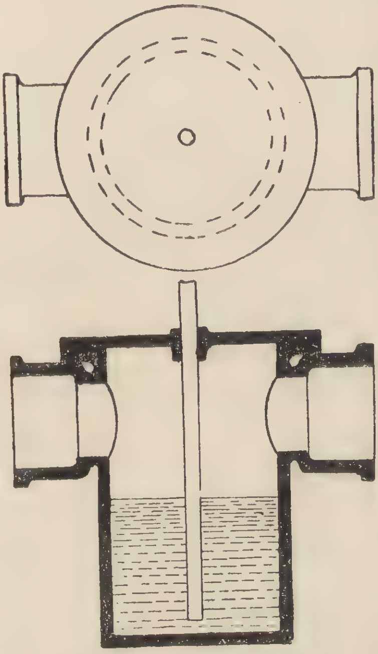


Fig. 23.

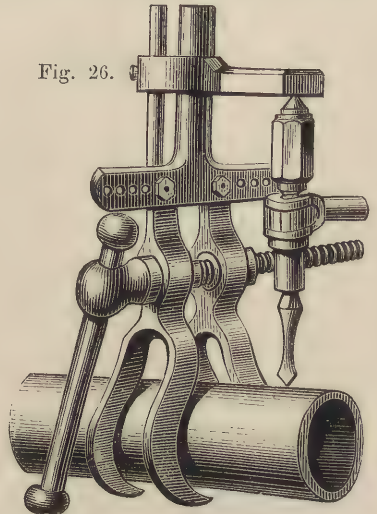
Fig. 24.

Figs. 23 and 24.—Plan and Section of Main Syphon.

is wedged sufficiently tight to prevent any escape of gas. Each pipe should be laid with the proper inclination or fall (say 1 ft. in 200 yd.), and there should be a cast-iron syphon or drip-well at the lowest point of the incline to collect the condensation water deposited from the gas; this would eventually clog the main, if allowed to accumulate. As a rule, gas leaves the works at a higher temperature than that to which it is exposed when passing through the mains underground; conse-

quently it holds more vapour in suspension as it leaves the works than it is capable of carrying with it through the district mains, the result being that the excess of vapour due to the difference in temperature deposits in the main and finds its way to the syphons. Fig. 23 shows plan, and Fig. 24 a section, of a syphon with its accompanying standpipe, to which the syphon pump is attached when pumping out the accumulated condensation products. There is no definite rule with regard to the number of syphons required for any length of gas main ; the principal factor governing their

Fig. 26.



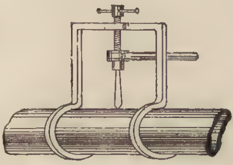


Fig. 25.

Figs. 25 and 26.—Methods of Drilling Gas Mains.

disposition is the inclination of the ground in which the main is laid. In refilling the trench in which a main has been laid, shovel in the soil in layers, and ram firmly and equally all round and above the pipes.

The hole for inserting a service pipe into the main should not be cut with a chisel, but should be drilled. The best position for the hole is at the top of the main ; a bend should be screwed in the hole drilled, proceeding thence with the ordinary piping, Only when the main is too high should the wrought-iron tubing be inserted at the side ; but it is better to lower the main than to insert pipes at the side. Care should be taken that the hole drilled in the main is not too large for the size of the main,

as a disproportionately large hole weakens the pipe, and renders it more liable to crack.

For drilling mains very simple tools are used, such as the ratchet-brace with an ordinary flat drill or with a twist drill; the twist drill is preferable, the ratchet being fixed in a bent iron hook as shown by Fig. 25, p. 51; or the apparatus shown by Fig. 26, p. 52, can be employed. These are the simplest forms of apparatus, but in using them the gas can escape when the hole is just through; and it is usually then the practice of fitters to close the

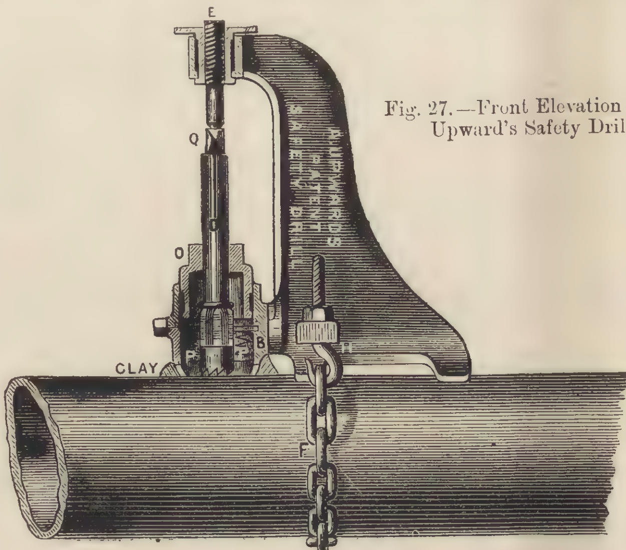


Fig. 27.—Front Elevation of Upward's Safety Drill.

space round the drill with a lump of clay or a piece of oily waste, keeping it pressed down to the main pipe with the left hand while the right hand works the ratchet handle. The loss of gas is not the most serious consideration, for it has been a frequent occurrence that men when working in a small hole excavated in the ground, with but little wind stirring, having been overcome by the fumes of the gas; and if this should happen when no one was near to render aid, it is very possible that death might ensue from asphyxiation. Should a man be overcome by the fumes of gas, milk should be given at once, as this is the best antidote.

In recognition of this danger, many inventions have been brought out for preventing the escape of gas when drilling and tapping mains. In some of these the drill passes through a hole in a sheet of indiarubber that covers the top edge of a cylinder, the latter being made to fit given sizes of mains by means of indiarubber rings; and the whole apparatus is screwed down tightly to the main by chains with tightening screws affixed being passed under it.

Another type of safety drilling apparatus is that known as

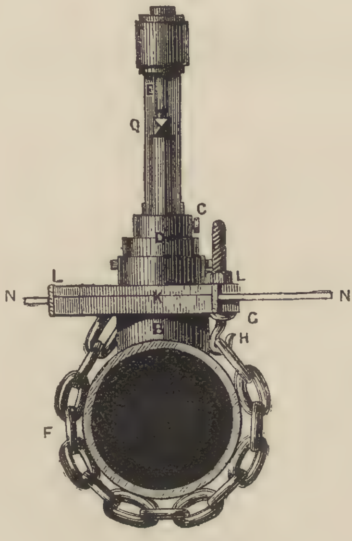


Fig. 28.—Side Elevation of Upward's Safety Drill.

Upward's patent safety drill; this is shown in front and side elevation by Figs. 27 and 28. For use, it is placed on the pipe in the required position for drilling the hole, the chain F being passed round the pipe and secured by the hook H; this is tightened up on the bridle G until the apparatus is firmly fixed. A roll of clay is placed around the bottom of the chamber B, to prevent the escape of gas, and the valve K is then opened with the handles N N, and the drill piston O, with the proper sized tap and cutter D in it, is placed in the chamber B. The drill is

allowed to drop on to the pipe, and the piston O is pushed down until it touches the spring P, the screw C being then tightened up. The ratchet handle is put on to the head of the drill at Q, the feed screw E is screwed lightly down on it, and drilling is commenced in the usual way, care being taken to feed the drill gently until it bites properly. As soon as the hole is through, the set screw C is loosened and the drill pressed down by the screw E until the tap bites. The completion of the tapping is ascertained by the tap coming home on the collar at its upper end. When this is done the drill is drawn up as high as it will go, and the slide valve K is closed carefully, to prevent the valve being injured in case the drill should by accident be left too low in the chamber B. To prevent the escape of gas during the operation the valve K passes through leather packings L L at the ends of the valve chamber. By the use of Upward's

Fig. 29.

Fig. 30.

Figs. 29 and 30.—Correct and Incorrect Positions of Drill.

appliance, the hole is both drilled and tapped at the one operation; and it is obvious that, if the above instructions are carried out, there can be no escape of gas through the hole made in the main.

Great care should be taken to ensure that the hole is being drilled in a radial direction from the centre of the pipe—that is to say, if the hole is being drilled in the top of the pipe, the ratchet and drill must always be kept truly vertical or upright, whilst if a side hole is being made, the drill must be truly horizontal. See that the drill invariably points to the centre of the pipe, as shown in Fig. 29: then the drill must necessarily be vertical. If the drill is held incorrectly, as in Fig. 30, the result will be that when the hole is drilled and tapped, the pipe that is screwed into it will not point in the proper direction. In feeding the ratchet-brace with the feed-screw, be careful not to exert the whole strength upon it, more especially when the drill is nearly through. The surface of the main being convex, the

hole at that time is not exactly round; hence, if forced too rapidly, the drill is apt to catch and bind.

When drilling a small main, and a service is required of nearly the same size, it is advisable to drill a hole some sizes smaller, putting in a short piece of small-sized pipe and increasing immediately to the size required. The short length of pipe of small diameter does not sensibly reduce the quantity of gas passed by the larger pipe.

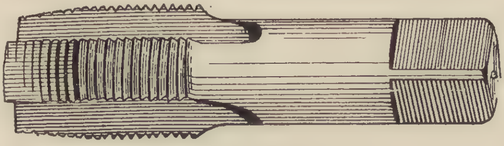


Fig. 31.—Taper Tap.

Hall's patent drilling and tapping machine is a strong and efficient tool, and its working principle is simple. Under the top flange of the machine is placed a circular revolving plate, through which the drill shank and cock carrier shank pass and rest in a seat, being held in place by a flat ring properly packed and bolted. The object of this plate is to enable the operator, after having drilled the hole and backed out the drill, to bring the cock immediately into position by revolving the plate, the holes in

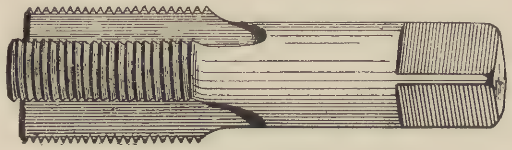


Fig. 32.—Plug Tap.

which are so placed that when it is revolved it brings either the cock or the drill over the same part of the main.

When a large hole is to be cut in a main a diamond-shaped chisel is commonly used—not, however, when the holes are afterwards to be tapped.

The taps employed for mains are of two kinds, taper and plug, as illustrated in Figs. 31 and 32, the taper being used first and then the plug. Before the tap is put into the hole it is advisable to see that the hole is cut cleanly through the main, as very often

there remains a portion at the sides that has not been cut away by the drill : such portion must be cut away with a hammer and cold chisel before the tap is inserted.

Very great care is necessary to ascertain that the drill used is of exactly the size necessary for the pipe that is to be inserted, and the best way of gauging the precise dimensions is to calliper the thinner end of the taper tap in the part that is of the largest diameter. The drill should then be made a shade larger than this, so that the taper tap may be inserted a short way into the hole, or a combination tool, as shown by Fig. 33, may be used. When the tap is in, a light blow on the top will cause the threads upon the tap to slightly enter the iron round it, and when turned by a key or spanner the tap will gradually force or cut its way into the hole, making the threads as it enters. Plenty of oil must be used on the tap, which must not be turned

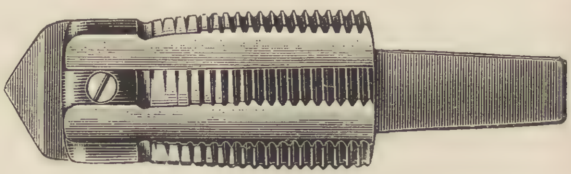


Fig. 33.—Drill Reamer Tap.

steadily in one direction, but must be taken, say, half a turn forward and then a short way back. Thus the cut is very gradual, and the metal cut away falls back into the grooves in the tap, leaving a clear way for that which is to be removed. Having turned the taper tap until it is as far in as the teeth will permit (being careful not to allow the tap to pass right through and drop into the main and so get lost), turn it gradually back until it is entirely free, and substitute the plug tap. Screwing this in and out again leaves the hole threaded ready for the pipe to be inserted.

During the whole of these operations it is usual to keep a piece of oily waste round the taps, ready to stop the hole when they are removed. Having plugged the end of the bend, either with a proper iron plug or cap, or with some of the waste before mentioned, and painted the thread with red and white lead paint, screw the bend into the main with the pipe tongs (see p. 68) until it will turn no further without great force, finishing with

the end of the bend pointing in the direction desired. Lead paint for gas-fitters' use is prepared by mixing about three parts of ordinary white-lead in paste with one part of red-lead in powder. For use as paint for threads of screws, boiled linseed oil is added to the mixture.

The service pipes should be of the best quality, and be allowed to fall towards the main. If that inclination is not possible, they should fall the other way, and a bottle syphon or drip-well be inserted at the lowest point to receive the condensation water, which accumulates as explained on p. 51. The service should be laid with a fall of at least 1 in. in every 12 ft.; and where the distance from the main is so great that this fall cannot be secured without bringing the service pipe too near the

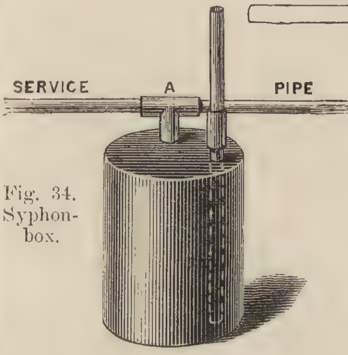


Fig. 34. Syphon-box.

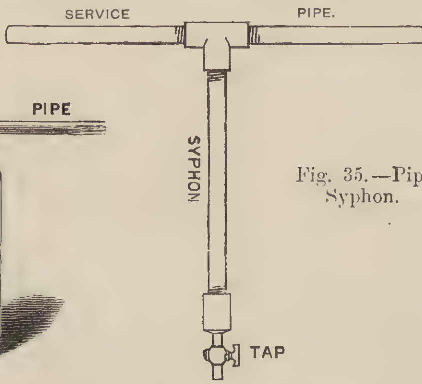


Fig. 35.—Pipe Syphon.

surface of the ground, it is best to rise from the main as far as possible, and then start falling again, putting in a syphon-box (as shown in Fig. 34) where the depth of the pipe is considered to be too great. In using the syphon-box, the pipes are connected to the tee shown at A, the upper portion of the tee forming a portion of the length of the service, the longer vertical pipe being carried up to an inch or so below the ground-level and a cap (not shown) screwed on it. This cap is usually made by using a plug fixed into a plain socket, the squarehead of the plug giving greater facility for removal for pumping.

With reference to the slope of the service pipe, it may be well to point out that, whereas in a wet meter the water condensed from the gas would help to keep the water in the meter at the

proper level and be an assistance, in the case of a dry meter its presence is decidedly objectionable; consequently, in laying the service to and the pipes from the meters, note must be taken of the class of meter which it is intended to fix, and when either the service or the pipes leading from it to the house happen to fall in the direction of the meter, a syphon should be used; this may be the syphon-box described on the previous page, or may be a pipe syphon as shown in Fig. 35, the condensation being removed from the bottom of the syphon from time to time, merely by turning the tap. These remarks with reference to meters will be more intelligible if taken in conjunction with the information given in Chapter V.

In pathways and where traffic is likely to be great, a cast-iron box with hinged lid should be fitted over the rising pipe of the syphon to preserve the pipe from damage. The service should not be allowed to come nearer than 1 ft. 6 in. to the surface of the road, as a covering of ground less than 18 in. thick is very porous, letting in sufficient moisture and air to ruin the pipe-metal within a comparatively short period. Greater depth also prevents rapid alteration of temperature and consequent condensation of the gas and deposition of naphthalene, which in time may be so great as to cause a stoppage in the pipe. Another reason why the service should be at a good depth is that the weight of any heavy road roller or any great load passing along the road will then be less likely to damage the pipe.

Services are usually made of wrought iron, and the tubes and fitting comprising them, such as tees, bends, elbows, sockets, etc., should be perfectly cylindrical, with no ribs or flat places, and internally as smooth as possible. The welding should be scarcely discernible from the other parts, and the screw should be equally deep throughout the thread. In laying wrought-iron pipes, the coupling or socket at the end, which is supplied along with the pipe, should always be removed and replaced after painting the thread with white- or red-lead paint. All service pipes, when laid in the ground, may be protected from the oxidising influences of the soil, moisture, and air, by being encased in a V-shaped or U-shaped wooden trough, and filled in with hot pitch and sawdust, to preserve the pipes, and, in fact, make them last more than double the time that they would if left unprotected.

The service of iron pipe having been carried through until it

has entered the house, a cock should be fixed, and thence a short piece of iron pipe leading just above the level of the meter and about a foot away from it. All meters should be fixed in positions where they will not be subject to rapid changes of temperature, but the place in which they are kept should not be so warm as to injure the leather bellows of the dry meters. The meter should be fixed on a wooden bracket attached to the wall of a passage inside the house, where it can be easily seen, so that any defect can be quickly noted and repaired; it should never be fixed in an inaccessible position, nor in a small cupboard with other things, for if a leakage occurred the cupboard would rapidly fill with a mixture that would instantly explode in contact with flame. The meter, especially a wet one, should be carefully put level, and fixed up with sufficient firmness to prevent shifting of position.

CHAPTER IV.

LAYING GASPIPE IN THE HOUSE.

THE preceding chapters having been devoted to the consideration of means and methods of supply, it is now convenient to deal with the means and methods of providing for the consumption of gas—namely, with the materials and operations relating to domestic gas-fitting. The requirements of the case having been ascertained, and the scheme of service having been carefully planned and arranged, measure up the lengths of iron piping required, making due allowance for threaded joints, bends, elbows, or tees. Bends should always be used where possible, as the quick alteration in the direction of the flow of the gas in elbows causes friction, and a consequent loss in the pressure obtained at the burner end of the piping. Then mark off the length with a piece of chalk, and fix the barrel in a pipe vice. Bends, elbows, tees, and other small fittings are shown in Fig. 36. Pipe vices are usually of the kind illustrated in Fig. 37, p. 63. The next proceeding is to hang the pipe-cutter on the pipe. The pipe cutter is a claw-shaped tool, with one or more hard steel cutting discs on the inside which can be made to screw in and out. A one-wheel cutter is illustrated by Fig. 38, p. 64; a three-wheel cutter by Fig. 39, p. 64; and two patented shapes of three-wheel cutters by Figs. 40 and 41, p. 64. Screw up the handle of the cutter until the wheel is exactly on the chalk mark, and give the cross-bar a slight turn so as to make the cutter-wheel enter the iron a little. Having put some oil where the cut is to be made, turn the pipe-cutter round the pipe once or twice, and take another slight turn on the cross-bar, continuing in this way until the pipe is cut through. A little oil on the cut assists greatly in the severing of the pipe, and, while saving the wear and tear on the wheel, also lessens the labour of turning the apparatus round. Several shallow cuts are much better than a few deep ones, as the deep cuts cause on the ends of the pipe a considerable ridge, which must be filed off before the dies can be used for threading; and as the thread at the end

of the pipe has to be made somewhat smaller and tapered, this ridge is especially objectionable. Having cut the pipes to the required lengths, it will be necessary to put the threads on them so that a gas-tight connection may be made with the sockets (see Fig. 36) which are obtainable ready screwed.

Fixing the pipe as before in the pipe vice, with a few inches of the end which is to be screwed protruding, pass a file round

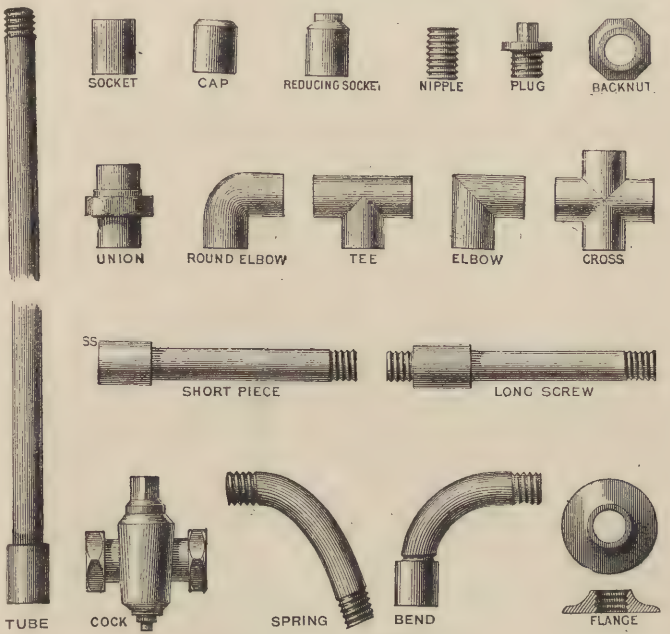


Fig. 36.—Tubes and Fittings.

the edges of the end to remove the burr caused by the cutter, and continue the filing until the portion of the pipe to be threaded is of even diameter.

The following table shows the dimensions of Whitworth's standard gas threads, with particulars of the diameters at the top and bottom. These threads are always used for gas and water pipes. The vulgar fractions in the third and fifth columns of the table are not exact, being to the nearest $\frac{1}{64}$ in. only.

DIAMETER OF PIPES IN INCHES.					THREADS PER INCH.
Internal.	*External.*		*At Bottom of Thread.*		
$\frac{1}{8}$	·3825	$\frac{3}{8}$	·336	$\frac{21}{64}$	28
$\frac{1}{4}$	·518	$\frac{33}{64}$	·451	$\frac{29}{64}$	19
$\frac{3}{8}$	·6563	$\frac{21}{32}$	·589	$\frac{19}{32}$	19
$\frac{1}{2}$	·825	$\frac{53}{64}$	·734	$\frac{47}{64}$	14
$\frac{5}{8}$	·9022	$\frac{57}{64}$	·811	$\frac{13}{16}$	14
$\frac{3}{4}$	1·041	$1\frac{3}{64}$	·949	$\frac{61}{64}$	14
$\frac{7}{8}$	1·189	$1\frac{3}{16}$	1·097	$1\frac{7}{64}$	14
1	1·309	$1\frac{5}{16}$	1·192	$1\frac{3}{16}$	11
$1\frac{1}{8}$	1·492	$1\frac{1}{2}$	1·375	$1\frac{3}{8}$	11
$1\frac{1}{4}$	1·65	$1\frac{21}{32}$	1·533	$1\frac{17}{32}$	11
$1\frac{3}{8}$	1·745	$1\frac{3}{4}$	1·628	$1\frac{5}{8}$	11
$1\frac{1}{2}$	1·882	$1\frac{57}{64}$	1·705	$1\frac{45}{64}$	11
$1\frac{5}{8}$	2·022	$2\frac{1}{64}$	1·965	$1\frac{31}{32}$	11
$1\frac{3}{4}$	2·16	$2\frac{5}{32}$	2·042	$2\frac{3}{64}$	11
$1\frac{7}{8}$	2·245	$2\frac{1}{4}$	2·128	$2\frac{1}{8}$	11
2	2·347	$2\frac{11}{32}$	2·23	$2\frac{1}{4}$	11
$2\frac{1}{8}$	2·467	$2\frac{15}{32}$	2·351	$2\frac{23}{64}$	11
$2\frac{1}{4}$	2 587	$2\frac{37}{64}$	2·47	$2\frac{15}{32}$	11
$2\frac{3}{8}$	2·794	$2\frac{51}{64}$	2·678	$2\frac{43}{64}$	11
$2\frac{1}{2}$	3	3	2·882	$2\frac{57}{64}$	11
$2\frac{5}{8}$	3·124	$3\frac{1}{8}$	3·009	3	11
$2\frac{3}{4}$	3·247	$3\frac{1}{4}$	3·13	$3\frac{1}{8}$	11
$2\frac{7}{8}$	3·367	$3\frac{3}{8}$	3·251	$3\frac{1}{4}$	11
3	3·485	$3\frac{31}{64}$	3·368	$3\frac{3}{8}$	11
$3\frac{1}{4}$	3·698	$3\frac{45}{64}$	3·581	$3\frac{37}{64}$	11
$3\frac{1}{2}$	3·912	$2\frac{29}{32}$	3·795	$3\frac{51}{64}$	11
$3\frac{3}{4}$	4·125	$4\frac{1}{8}$	4·008	4	11
4	4·34	$4\frac{11}{32}$	4·223	$4\frac{1}{4}$	11

Three kinds of stocks and dies are in use for screwing the pipes. Those that are most commonly employed are the straight stocks and dies, as shown in Fig. 42, p. 65. These can be made to perform all the operations of which the others are capable. The taper die-stocks (Fig. 43, p. 65) are quicker to work, for they give a full thread at one threading, and, unlike the straight dies, these have guides which keep them square when starting the screwing of the pipe. This is a great advantage, as connections on which the threads have not been properly and

squarely made are very unsightly. Again, with the taper dies the two halves of the dies are tightened together before commencing the screwing, whereas with the straight dies the two halves have to be opened sufficiently to allow the pipe to

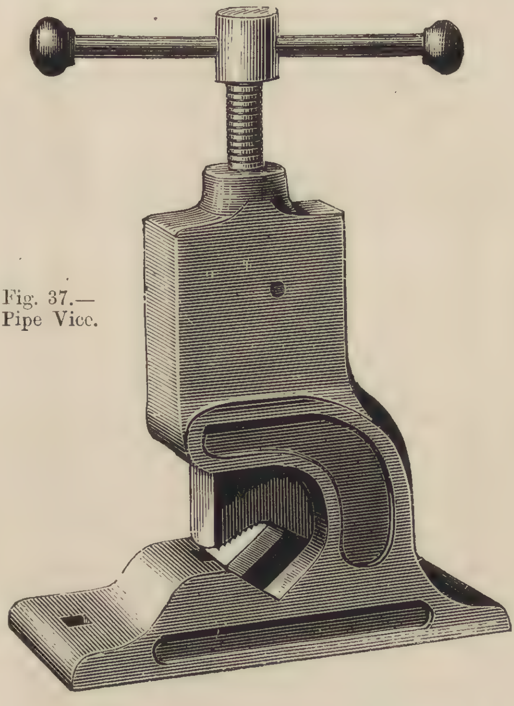


Fig. 37.—
Pipe Vice.

enter between, and, when straight, must be screwed up gradually as the thread is being made on the pipe.

If the thread is not exactly straight at the start, the remainder of the work will be thrown still further out. To avoid this mishap place the pipe vice on the edge of the bench, and fix a pipe in it, screwing down the vice so that the pipe is at right angles with the face edge of the bench; then the stocks and the dies can be held horizontally, and it can be easily seen whether they are parallel with the edge of the bench.

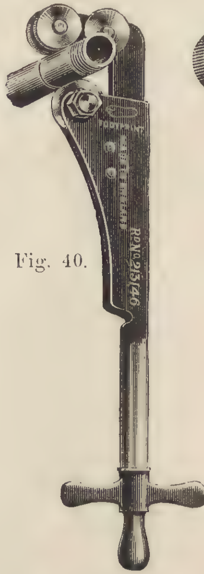


Fig. 40.

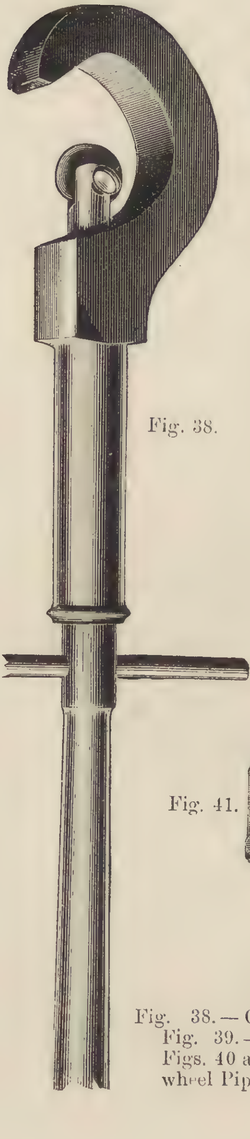


Fig. 38.

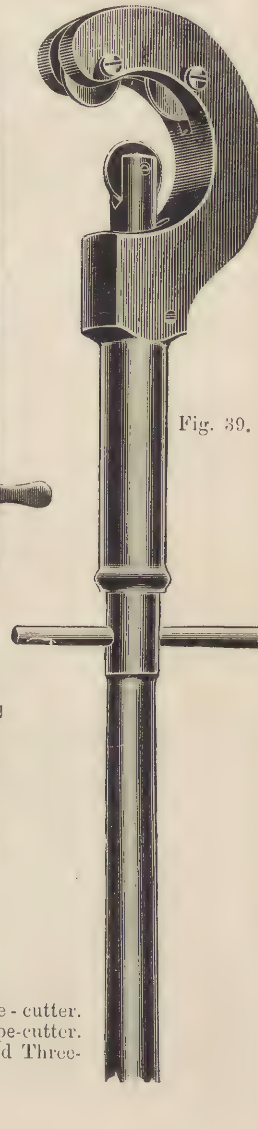


Fig. 39.

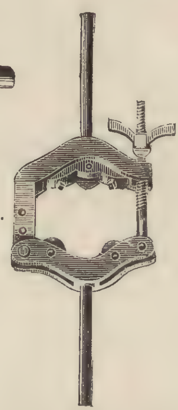


Fig. 41.

Fig. 38.—One-wheel Pipe-cutter. Fig. 39.—Three-wheel Pipe-cutter. Figs. 40 and 41.—Improved Three-wheel Pipe-cutters.

Fig. 42.—Stock and Die.

Having inserted the pipe end between the two halves of the dies so that the end of the pipe is about flush with the face of the dies, screw up with the hand the handle of the stock as tight as it will go, and then, inserting a short bar into the hole in the handle, give it about an eighth of a turn more; this will cause the dies to s'ightly enter the iron. Next thoroughly oil the dies and the pipe to be cut, and take a steady turn or so with the stocks so as to start the threading, when the dies may be tightened slightly more. In this operation, as in cutting pipes, avoid deep cuts, which tend to wear out the dies, whilst the thread cut is not nearly so clean; and care must be taken that there is always a good supply of oil at the cutting point. It is desirable to give the thread a slightly taper shape, and this is done by slightly and gradually tightening the dies as the stocks are worked off the thread. In turning round the stocks take half a turn and then go back, say one-eighth of a turn, so as to clear the dies and allow the cuttings of metal to get into the grooves made in the dies, and thence to fall out.

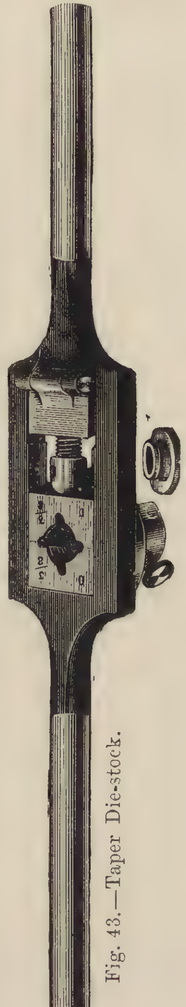


Fig. 43.—Taper Die-stock.

It is better to tighten up the dies at different parts of the thread and at different parts of the turns, so that the deeper cutting in of the thread shall not commence always in the same place. The error indicated is one which the gas-fitter is very apt to commit, as he usually places the short lever in the same place each time he uses it, and consequently stops at the nearest points of the turn to this place when he again wishes to tighten up the dies. When the thread is considered to be cut sufficiently deep to allow a socket to fit on it, the dies must be either run off by turning the stock round, or else the handle must be loosened, when the dies can be opened out. It is well to have a socket or tee of the right size ready at hand to test the size of the thread, the said pipe having about six to eight threads on it, thus ensuring a really good joint. One of the great advantages of the taper dies is that the threads are certain to be cut down to the proper size at the first operation, so that the stocks have never to be placed again upon the thread, as is the case with the straight dies. Straight dies, however, must sometimes be put on the thread again, to reduce the diameter of the thread, and then great care must be taken that they are put into the old threads, or new threads will be cut on the old ones, and consequently the whole thread ruined. To avoid such a disaster, proceed as described on p. 63 for first putting on the stocks, by holding them parallel to the edge of the bench.

The third method of screwing pipes is that by means of a screwing machine; this is usually made with adjustable dies, which not only effect a considerable saving in time, but ensure much better and much more even work than either of the two methods already described. Unfortunately the machine is not very portable, but in a workshop where sufficient pipe-screwing is done to justify the purchase of the machine, it is most valuable, as, during periods of slackness odd portions of piping can by its means be screwed and made into nipples, short pieces, or connectors; in fact, in some shops it is usual to keep a boy constantly employed on such work.

The screwing machine shown in Fig. 44 needs but little explanation. The pipe is fixed in the vice and tightened by the screw shown at the top of the figure; the end of the pipe is then brought close to the dies by means of the arms at the side, which actuate a pinion that gears into a rack on the under-side of the vice. When the pipe has entered the dies,

which are tapered, and should be set to the exact size of the thread required, the handle that gears with the disc containing the dies is turned, the dies cutting their way gradually into the pipe until the thread is completely formed, whilst the pipe is drawn gradually into the dies. A large number of these machines are also fitted with a cutter, which can be used for dividing the pipes into the lengths required. Some of these machines are so arranged that there is no backing off the dies when the thread is finished; all that is necessary being to open out the dies and run the pipe vice back.

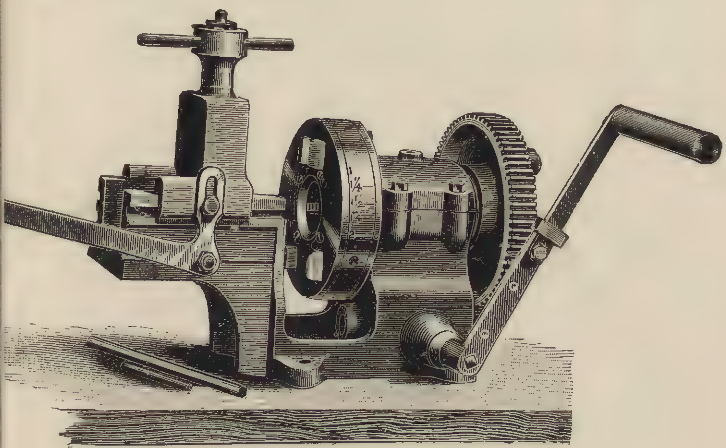


Fig. 44.—Screwing Machine.

The joints in the iron pipes are usually made by threading externally the ends of the pipes and fixing sleeves or collars, or sockets as they are usually termed, on these ends, the sockets being threaded internally to suit the thread on the pipes; and for ordinary purposes this joint will be all that is required. But there are occasions—as, for instance, when two outlets are required somewhat close together—when some other means will be desired, and then the common method is to put in what is called a nipple, which is nothing more than a $1\frac{1}{4}$ in. length of pipe, threaded externally from end to end (see Fig. 36, p. 61). This, having been painted, is screwed half-way into one of the tees, and then the other is screwed on to the remaining half, a

few strands of yarn being twisted round the joint before it is screwed up tight. This is by no means the only way in which the nipple is useful, but will serve as an example of the ordinary method of employing it.

There are several kinds of pipe tongs in common use, but Fig. 45 shows the one generally employed. Some are made with a screw so as to suit several sizes of pipes; a parrot-bill pipe wrench is shown by Fig. 46. The professional gas-fitter will require a complete set of pipe tongs, and when purchasing these, care should be taken to see that they are of good quality and strongly made, otherwise they will be in frequent need of straightening.

The screwing in of the nipple is sometimes a matter of difficulty, especially when the nipple, or the tee, or the elbow, has become slightly rusty. The common method of screwing is to fit the nipple into the proper dies, clamping them tight on the

Fig. 45.—Pipe Tongs.

half that will be left outside the first tee, thus holding the nipple securely without the threads. But the time taken in getting the proper dies into the stocks and screwing them up again into the nipple is considerable, and consequently an impatient or careless workman is liable at times to use his tongs on the thread, which may be ruined thereby. The thread is slightly injured even when the stocks and dies are used, as the cutting edge of the die is sure to enter the metal to a greater or less degree, according to the amount of pressure applied to the lever for tightening the dies round the nipple. A comparatively new appliance, called the Ashley nipple-holder, obviates all these defects. Sockets of different sizes are provided, into which one half of the nipple is screwed; when it is sufficiently in, a plunger is forced into contact with the edge of the nipple, and the teeth on the plunger enter into the metal where they can do no damage, but at the same time they prevent the nipple turning and ensure its entry into whatever socket is ready for it.

The connector is a joint of very great use, and should be employed far more frequently than it is, especially where extensions or alterations are at all likely. The connector costs rather more than the socket, but is of great value when from any cause piping has to be taken up. The few pence expended on its purchase will be repaid the first time a leak occurs or that the piping has to be cut to fix a connection for, say, a gas stove or an extra light. As pointed out on p. 66, with reference to the screwing machine any short pieces which may remain from the cuttings in the shop can quickly be made into connectors, which are simply short pieces of pipe externally threaded at both ends, but with the thread at one or both ends cut sufficiently far to allow the ordinary socket and a back nut to be screwed wholly on to the piece of pipe.

The great advantage of the connector is that by its use certain

Fig. 46.—Pipe Wrench.

lengths of pipe can be screwed up together, and bends and tees fitted on and connections led from them, and these can afterwards be joined together by means of the connector. This advantage is best appreciated when the gas-fitter is working in close quarters or in awkward corners.

The pipes having been cut and joined up at the far ends to the fitting or supply, a connector is chosen of the exact length to go into the space between the two pieces of pipe, and the back nut and socket are screwed right up on the connector, the other end of which is then screwed in the ordinary manner into the socket of one of the pipes; and then the end of the other pipe is brought exactly opposite the free end of the pipe. When this is on tight, the back nut is brought close up to the socket, and after a few strands of yarn have been wrapped between, is screwed up quite tight against the socket, thus effectually preventing any escape of gas, which would otherwise take place owing to the socket being somewhat loose on the pipe forming the connector. Paint made as described on p. 57 is required on the connector as well as on all other joints in iron piping.

The chief points to be observed in the manipulation of iron tubing having now been dealt with, it will be convenient, before treating of special fittings, to describe the use of composition (or, as it is usually called, compo.) pipe, which is made from an alloy of tin, lead, and antimony, the proportions varying greatly. In making the pipe, the alloy is placed in a reservoir or container over the piston of a hydraulic press, so arranged that it can be heated by an annular fireplace. The reservoir is filled with molten alloy by a spout through an aperture in the top; when the reservoir is full the spout is taken away and the orifice closed tightly by an iron plug kept in position by an iron key. A steel die fitted at the top has in it a hole of the size of the outside of the compo. pipe, and this regulates its external diameter, the internal diameter of the pipe being determined by a mandrel, which passes directly through the centre and is moved upwards

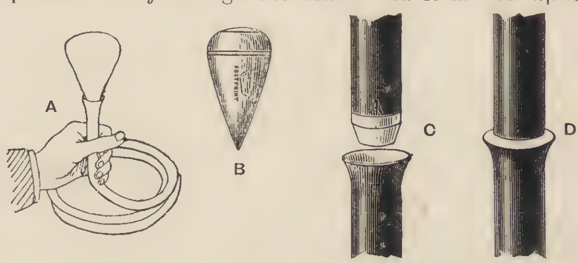


Fig. 47.—Method of Jointing Compo. Pipe.

by the rising piston, the semi-fluid metal being at the same time forced through the die. The metal cools down as it is forced away from the foot of the mandrel and cone, until at a certain distance it becomes sufficiently cool and hard to be coiled round a drum.

In the first place, it is desirable to describe the usual method of connecting the compo. pipe to the end of the iron tubing. The end of the iron tubing having been screwed in the usual way, a union, made of brass, is fitted to it; these unions are of two kinds, the barrel union and the cap and lining union. The barrel union consists of a sleeve of brass tubing, with an internal or socket thread suitable for screwing on to the end of the pipe, and a short outside or spigot thread at the other end of the sleeve, on which screws a hollow nut which serves to draw up a second sleeve of brass, which is usually tinned. The hole at the

top end of the nut is smaller than that where the thread is, and this prevents the collar on the second sleeve from passing through, a gas-tight joint being made by means of a ring of leather between the collar and the nut.

The cap and lining union is similar, except that in this the nut screws directly on to the iron piping and the first-mentioned sleeve is not required. It having been ascertained that the union will fit the iron tubing, the union should be removed, and re-tinned so that the solder may quickly join to the metal; the tinning done by the makers is rarely sufficient to ensure a good gas-tight joint. In re-tinning with a soldering-bit, the sleeve is held on its side by a pair of pliers or pincers, and the sleeve having been well powdered with resin, a hot soldering-bit is passed round it until the solder has run all over the part that will afterwards be required to be joined to the compo. pipe,

Fig. 48.—Shave-hook.

plenty of solder being kept on the bit. When the re-tinning is done by means of a blowpipe, the solder is made to flow round the sleeve in the same manner, a spear of flame being directed on to the solder and on to the part to be tinned. By this means a smooth and at the same time thin layer of solder is run over the sleeve, which will quickly make a joint with the solder used when the joint itself is being made. The methods of using both soldering-bit and blowpipe are described in detail below.

Joints between compo. and lead pipe, or between two pieces of compo., or between either of these pipes and brass piping, can be made in either of the two ways just described—that is, with a well-tinned soldering-bit or with the blowpipe. In joining two pieces of compo. pipe of equal size, it is usual to turn the one end of the compo. pipe until it points directly upwards, then, with a plumber's top (B, Fig. 47), usually made of boxwood, the end is opened by lightly tapping the top with a hammer, or simply by twisting the top, keeping a pressure downwards on the pipe, taking care to hold the compo. pipe just below the part being opened out (as at A,

Fig. 47). The pipe should be made sufficiently large at the end to just allow the end of the other piece to be inserted in it. Then the opened end should be cleaned with a scraper (Fig. 48, p. 71), or with a penknife. The scraper, which is really a plumber's shave-hook, is also of use in cutting off the length of pipe required from the coil. Having cleaned the inside of the opened end, cut off the top edge cleanly, and carefully clean and scrape the end that is to be inserted for about ½ in. up, scraping off more near the end, so that it is slightly bevelled (C, Fig. 47, p. 71). Put it into the opened end, and, holding one piece in each hand, force them tightly together until they hold of themselves. A little powdered resin and oil, mixed, is put into the joint to act as a flux. This mixture is prepared by melting resin in a ladle over a fire and adding any common oil to it, and well mixing, taking care that it does not become too thick. If a blowpipe be used—and this is certainly the quickest method—the solder required is specially prepared, and is known as blowpipe solder. If a spirit blowpipe is not available, an ordinary mouth blowpipe, also some rushes soaked in tallow, or an ordinary tallow candle, may be employed. The rushes or candle are held in the left hand, the mouthpiece of the blowpipe is placed in the mouth, and a strip of solder is held in the right hand. Blowpipe solder is made in thin sticks, so as to be more readily heated and bent close to the point at which it may be required. Such blowpipe solder should consist of two parts of pure tin to one part of lead, while ordinary solder seldom contains more tin than lead, and plumbing solder contains only 1 part tin to 2 parts of lead. A simple test for the quality of solder is to bend the stick close to the ear, when, if the solder be good—that is to say, if it contains a fair proportion of tin—a distinct crackling will be heard; whereas a common solder will bend without any noise at all. Having bent the solder so that it will easily get into the joint, light the tallowed rushes, and hold them a short distance from the solder; with the blowpipe blow a clear and steady blast, and so cause a small spear of flame to stand out from the remainder. This spear will be of an intense heat, owing to the excess of oxygen supplied. The point of the blowpipe is kept about ¼ in. from the flame, which must be directed on to the joint in process of making, the solder at the same time being held against the joint until it begins to melt. Hold the extreme end of the stick of solder in the spear of flame, and dip it, when heated, into powdered resin until a small

quantity adheres to it. Now hold this resined end of the solder close to the compo. pipe at the joint, and with the blowpipe and rushes send a spear of flame upon it and the joint; this will melt the solder, and at the same time heat the compo. pipe sufficiently to cause the solder to adhere to it. Then work round the joint until the cavity is filled up and the two ends of the tubes are fastened together and neatly flushed up all round (D, Fig. 47, p. 71). By a slight movement of the blowpipe the solder can easily be made to run round the joint, and, adhering to both pieces, join the two together. This, when a blowpipe is used, can be as easily done on the side as vertically, but with a soldering-bit an upright position is desirable. With new pipes resin is not so necessary; it will suffice to rub the rushes round the joint or put a little Russian tallow upon it, when the solder will run easily round the joint. Even with old pipe a rub with tallow is advisable; by its use the joint can often be made neater, and may require less solder. To make a really good blowpipe joint a fair amount of practice is required; but even an unskilled person will probably succeed if the pipe be painted just above and below the joint with a mixture of size and whiting, so as to keep the heat from the pipe, except just at the joint.

Blowpipe lamps, of which many varieties are now sold, are very handy, and save both time and money. In many of these benzol is used, and while some are only lamps with tubes attached, which have to be blown through in the same manner as the ordinary pattern blowpipe, others have an arrangement by which the heat of the flame causes a current of air to pass through and direct the spear of flame on to the part to be soldered.

When a soldering-bit is used, the same method as that described with reference to the blowpipe joint is adopted for cleaning, scraping, and joining the two ends; but when the ends are pressed together, preparatory to the use of the soldering-iron, the edge of the lower has to be covered with resin, and, the worker holding a stick of solder in one hand and a hot, well-tinned soldering-bit in the other, the compo. pipe and solder are heated and joined, the soldering-bit being slowly carried round the joint and the solder made to flow evenly round after it. Care must be taken that the iron is not too hot, and that it is not kept too long in one place, or the compo. tube will be melted; melting also occurs when the blowpipe is used, if the

flame be kept playing too long on the pipe. In all shops where compo. pipe is used there are plenty of short pieces that can be utilised by the novice in practising. Many apprentices are kept making joints in pieces of compo. pipe. This practice serves to utilise the shorter pieces, as well as to render the apprentice proficient in this, the most difficult of gas-fitting joints; but in other respects it does not pay to join up these pieces, as the cost of compo. pipe is so small, and a fair price can always be obtained for the old material.

When cutting off a length of compo. pipe, allow sufficient to bend upwards in making the joint if a soldering-bit is to be used; and when bending compo. pipe care must be exercised lest in the process the pipe becomes closed up and rendered useless. The usual way is to make the bend with a very easy curve at first, and gradually to reduce this until a bend of the required size is obtained. Hold the pipe in the left hand, with the thumb on the inside of the bend, and, using the thumb as a fulcrum, bring the remainder of the bend slightly round; then shift the thumb a short distance and proceed as before.

It is sometimes found difficult to measure from the roll the compo. pipe required for a given position. When the operator is working single-handed, the best way is to put a moderate weight on the free end, and roll the remainder along the floor, when the pipe will come out practically straight; but when a mate is present, by each holding the ends of the piece to be cut off, and giving a good pull, the pipe can be made perfectly straight and the exact length carefully measured. The length of a coil of compo. may be roughly calculated by counting the number of coils and multiplying by three times the average of the inside and the outside diameter. This is only roughly correct, as it should be three and one-seventh times, or, to be still more exact, 3·1416 times. Compo. pipe should always be unrolled, not lifted off ring by ring, or it will become twisted, and probably the passage-way for the gas will be reduced in area.

In fixing compo. pipe on walls and in floors, care must be taken that it is laid in such a way that no sagging or loops shall develop in the future, as these form most effective traps for the catching of any condensation which may be caused by variation of temperature, and so in time stop the passage of the gas through the pipe. To prevent this, the pipe hooks should be driven in at short intervals, and hammered in so far that they

hold the pipe close to the wall, yet without the head or hook of the nail bruising the pipe.

In straightening the pipe, slight blows with a hammer are very useful, the pipe being supported in the hand. When working in a corner or close to the architrave of a door or window, the pipe may be driven well home by means of light hammer blows; to ensure good appearance, the pipe should be made perfectly straight. A piece of compo. pipe which does not follow the exact line of the corner or the woodwork against which it is laid looks very unsightly.

In putting compo. pipe in a house which has been plastered and papered, and in which the pipes are to be laid outside the finished walls, it is well to follow either the architrave of door or window or a corner of the room, as the projection of the wood in the former case hides most of the piping. An advantage in laying gas-piping on the outside of walls is that, should leakage at any time occur, the pipes can be readily examined, and any escapes promptly stopped. To prevent the pipes showing, an excellent plan, when designing a new house, is to arrange the woodwork so that a portion can be readily removed, and the pipes laid in behind. Many houses have boards laid up the walls, behind which the supply pipes are carried. The various branch pipes, being carried along under the flooring, do not require boxing in, and the only portions of the pipe not readily accessible are those leading to brackets on the walls.

Many escapes are caused by people hammering nails in the walls on which to hang pictures, the nail penetrating the compo. piping and causing leakage; when, therefore, pipes are to be laid in the plaster, iron pipes should be used, even if compo. pipe be used in the ceilings. A most useful accessory for gas-fitters using compo. pipe is a length of pliable cane; by probing with this the gas-fitter can readily ascertain whether a length of compo. pipe can be made to pass. Anywhere that the cane can be made to go the compo. pipe can easily be made to follow. The cane is also useful for measuring the length of compo. pipe required for traversing corners or curves.

When pipes, either compo. or iron, are laid in walls before plastering has been commenced, or where the plaster has been cut to allow the pipe to be afterwards embedded in it, care should be taken to ascertain that all the pipe hooks are properly driven

home, so that none of the heads protrude beyond the finished line of plaster.

Various ways of making joints in both iron and compo. pipes having been described in sufficient detail, the next subject to consider is the fitting up of the various lights in a building.

The usual, and perhaps the best system of lighting—especially in a dwelling-house—is to fix a pendant in the centre of the ceiling; and the light from this, which may contain any number of arms, is sometimes augmented by brackets placed round the room.

In fixing pendants in a finished building it is often found that a rose or centre-piece fixed on the ceiling defines the exact position for the hanging light; but when the gas-fitter has to decide the matter he is fortunate if the centre of the ceiling is found near a joist.

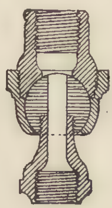


Fig. 49.—Ball and Socket Joint.

Most pendants (often erroneously called chandeliers, which signifies, literally, candle-holders) have, and all should have, a ball and socket joint. The ordinary pattern of such a joint is shown by Fig. 49; this joint enables the pendant to swing in any direction, so that it may, on occasion, be held out of the way of a passing object, or, in the event of an accidental knock, allow of play or movement of the pendant, and thus prevent loosening or breakage. The ball and socket joint should be taken to pieces in the shop, well greased with tallow at the movable joint, and if the joint is found leaky, a little powdered emery should be ground in. This should afterwards be carefully cleaned off, more tallow laid on, and the whole put together again and tested. Very firms supply their fittings of such quality as to be always gas-tight, but first-class firms test all their fittings most carefully before selling. Each end of the ball and socket joint is usually fitted with an internal thread, so that the pipe from the pendant can be screwed into one end, and a short piece of pipe, to pass through the ceiling, into the other. This short piece of pipe should be of sufficient length to reach a tee on the pipe running across the joists, thus connecting the pendant to the gas supply, and should also serve to carry the weight of the pendant, the supply pipe being carried beyond the tee with a short piece of pipe having a capped end, which will lie on the next joist, and so

form an additional means of support. Should it be decided, however, to use compo. pipe, or should the iron supply pipe be running in the same direction as the joists, the best method to adopt is to fix what is known as a bridge-piece between the joists, and the simplest manner of doing this is to nail a narrow strip of wood to each joist, and rest the ends of the wooden bridge-piece on them as in Fig. 50. In the exact position over the hole in the ceiling, a hole should be drilled, through which the short piece of pipe from the ball and socket joint can pass, with a fairly close fit, and if a long thread be put on the upper end of the pipe, a back-nut can be put on before the union of the cap and lining is screwed on ; the back-nut should then be turned back until it forms a guard to the union to prevent the latter unscrewing (see Fig. 50).

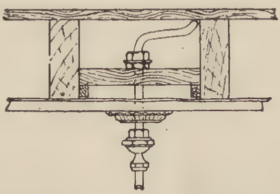


Fig. 50.—Bridge-piece Pendant Fitting.

As it often happens that gas-fitters are required to clean old pendants, brief instructions in the method of doing such work may be fitly given here. A common form of pendant is selected as an example. Take the principal parts to pieces, screw the arms out of the centre body, and remove the bottom knob, etc., taking notice of the way in which the several parts are fitted, as this knowledge will be useful when putting together again. Then remove the old lacquer by immersing in a strong hot lye, consisting of 1 lb. of carbonate of soda or potash to 1 gal. of water. Take out the plugs, and mark them so as to be able to replace them in their proper tops, and be careful not to lose the screws. Tie loose parts to pieces of copper wire, and dip in aquafortis, swilling quickly afterwards in running water. Alternate the dipping and the swilling until the parts are thoroughly clean, and finally swill well in water. Finish by dipping in clean water made slightly acid with cream of tartar, and dry out in saw-dust of box or beech. Dip each arm, outside and inside rod, pulley-frame body, and watercup separately. The smaller parts, such as screws, can be dipped together in a porcelain or wicker basket. Burnish prominent parts with a hard steel burnisher, using oxgall or stale beer to lubricate the burnisher. Hold in wooden clamps while burnishing ; swill occasionally in water containing cream

of tartar, and, when finished, dry out in sawdust as before, remembering to keep everything perfectly clean when burnishing. Lacquer on a hot plate or in an oven. To put the pendant together, place white-lead mixed with oil on all the screws, and beeswax on the plugs. Screw the arms up very tight, outside rod and ball joint, exhaust the air with the mouth in order to test the joints for soundness, and blow water down as a test for leakage. It is often advisable to procure new brass chain, as the old one is apt to become rotten.

In a building in which the floor-boards have been laid, the common method of finding which board should be removed is to drive a gasfitter's long gimlet from below straight up through the boards into the room above. To remove a floor-board that has been laid down is a somewhat difficult matter, unless the proper method is followed, and that is to drive the nails right down

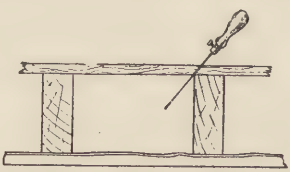


Fig. 51.—Method of Sawing Floor Board.

into the joist by means of a carpenter's punch ; the nails will not be required again, as, after the work is done, the board should be fastened down by screws, preferably of brass, and with brass countersink cups or washers, so that the screws may be easily removed when it again becomes necessary to examine the gas-pipes underneath. When the board runs the whole length of the room and under both skirtings, there are two usual ways of proceeding. One way is to lever up the board from each side until a piece of iron pipe, or a hammer-handle, is inserted under the board to be removed, and resting on the boards on each side, and then with a saw cut through the board over the centre of a joist. If the joist cannot be seen, the old nail-holes will be a sufficient indication. When the board has been cut in two, either piece can be easily taken up. The other method—particularly useful when only a short piece of board is to be removed—consists in cutting the board with a keyhole saw on the slope close to the joist, as shown in Fig. 51 ; to start the saw, bore a hole

with a large gimlet. When refixed, the board cannot be tipped up, and nails can be put in on the slant into the portion of the board already fixed, and right into the joist.

Where the pipe runs at a right angle to the joists in the floor, the usual method is to cut a groove in the joists sufficiently large to allow the pipe to lie in it and not be injured when the boards are nailed down over it. These grooves should never be cut deeper than necessary, and should always be cut as near the points of support of the joists as possible, so as not to weaken the beam ; but it may be pointed out that all parallel beams are stronger near the points of support than is absolutely necessary, the strain diminishing as the side approaches. It will be seen, therefore, that at the sides of the room where the joist rests on the walls a portion of the joist can be removed with safety, but that nothing should be cut away from the middle. The adoption

Fig 52.—Supporting Pipe at Side of Joists.

of this precaution will often necessitate the use of a greater length of pipe, but in many cases a careful survey of the premises will enable the gas-fitter to arrange his pipe so as to suit the joists in the floors, and at the same time to obviate the necessity of using more pipe than would be required if it could be carried through the centre of the joists. When compo. pipe is being used, and has to be carried along the side of a joist, it should not be allowed to lie on the ceiling-laths, or a dip would occur, with consequent accumulation of moisture and stoppage of the gas supply. The pipe should always be fixed to the side of the joist by means of blocks of wood of one of the patterns shown by Fig. 52, which illustrates two sections of a floor at right angles to the joists.

In fitting up brackets, it is usual to carry the compo. pipe to the spot at which the bracket is to be fixed, which should be at least 2 ft. 6 in. from the ceiling, or the latter will become quickly blackened by the accumulation of dust on the vapour that the

burning of the gas causes to condense on the cold ceiling. Nevertheless, the bracket should be kept sufficiently high to be out of the way of people's heads.

The spot having been selected, the compo. pipe is brought to within 2 in. of it, and then what is commonly known as an elbow tube-bit is fixed to it. This is usually made of a piece of brass or copper tube of about $\frac{5}{16}$ in. or $\frac{3}{8}$ in. diameter. It is made in the form of an elbow, the short end being screwed and the long end tinned; the tinned end is for connecting to the compo. pipe. Tube-bits can be bought ready-made at about a penny each, and are ready tinned, but time and trouble may often be saved by re-tinning (see p. 71) them before attempting to make the joint. By the expression tinning is understood the coating of the tube with a thin layer of solder, which is done by dipping the end of the tube into resin, and then subjecting it to the heat either of the blowpipe or of the soldering-iron, when the solder is made to flow all round. By tapping the end of the tube on the bench while still very hot all the surplus solder is shaken off. During these operations the elbow tube-bit should be held by a pair of pliers or pincers, as the metal, being a good conductor of heat, will very quickly become too hot throughout its entire length to be held by the hand. If the tube-bit is made from a fresh piece of tube, and has never been tinned, it is necessary to thoroughly clean the metal wherever the tinning is required to adhere before the above process is started.

The compo. pipe is now opened out with the plumber's top or turn-pin, as described on p. 71 for the connecting of two pieces of compo. pipe, and well cleaned; then the tube-bit is inserted in the open end and pressed into it until it holds of itself, when, by means of a blowpipe or a soldering iron the fine solder is carried carefully round the edge of the compo. pipe, thus forming a good joint between itself and the tinned side of the elbow tube-bit. The wooden block or pattress is now placed over the tube-bit, the screwed end being passed through the hole in the centre, from which it will protrude about $\frac{3}{8}$ in. These pattresses, finished to represent mahogany or ebony, are to be bought very cheap, and can be had either with a groove at the back for the compo. tube to lie in, or without the groove when the pipe is carried through the wall or partition. Should the groove be required and only ungrooved pattresses be at hand, the groove can be made easily by fixing two pattresses

back to back, with some paper or other soft substance over the faces, in the vice; then the pattresses can be drilled up to the centre with a $\frac{3}{4}$-in. centre-bit, half the cut being taken out of each block, and forming a semicircular groove in which the small-bore compo. pipe can lie.

In fixing the pattress to the wall, if the latter be of wood, it is of course only necessary to screw the block direct to it; but the wall, if of brick, must be plugged before putting in the screws. It is best, when gas-fitting is being done before plastering, to cut blocks of wood the size of half a brick and have these tightly set into the wall with mortar; after the wall is plastered and painted, however, smaller wedges, into which the screws are driven, must suffice. The screws should invariably be countersunk into the blocks, so that nothing may prevent the back-plate of the bracket from lying flat on the pattress; and the same instruction applies to the holes to be drilled in the back-plate of the bracket, which is not supplied ready drilled, as the holes cannot be made until the position of the pipe-lead and of the screws in the pattress are known. Another reason for countersinking these screws is to remove any rough edge, which, if left, might afterwards catch the hands or dusters when cleaning the bracket.

Having decided on the positions of the holes in the bracket back—generally three in number—so that they shall miss both the pipe and the screws already in the block, screw the bracket on to the protruding end of the tube-bit (previously painting the thread of it with the red-lead paint mentioned on p. 57) until the back-plate is close to the wooden block and the bracket is the right way up; then drive in the three screws, and the bracket is fixed; the screws are short, as they have to go only into the block. When drilling the holes in the back-plate, it is usual to take the swivel out of the socket by undoing the small set-screw at the bottom, being careful not to lose the little washer which fits on the bottom of the swivel; by thus removing the swivel the gas-fitter has ample room to drill the holes with a brace or with a machine drill, and at the same time the opportunity may be taken to wipe and clean the swivel and socket and re-grease them before fixing, as many of the joints in the brackets now made are not very carefully ground in; the consequence is that shortly after the work is done complaints are made that there is an escape of gas—a contingency that might have been avoided if the grease that is always put on by the

maker, but which gets hard when laid by in stock, had been removed, and fresh grease (tallow) substituted.

Sometimes a bracket is fixed for the purpose of connecting the supply of gas, by means of flexible tubing, with a pedestal lamp on a table or shelf, and when it is known that this is to be done the bracket and pattress should be fixed more firmly, as the moving of the lamp is likely to cause a considerable pull on the connection. In such a case the bracket must be firmly attached by means of wooden wall-plugs, into which the screws

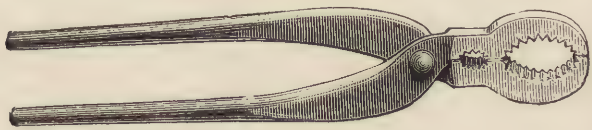


Fig. 53.—Gas-fitter's Pliers.

are inserted; better still, a wooden block should be set into the wall. The gas-fitter will need for almost constant employment a good pair of pliers; their uses, though chiefly in connection with the screwing in of burners, are too many to be enumerated here, but the usual shape of these tools is illustrated by Fig. 53.

CHAPTER V.

GAS METERS.

The structure of the gas meter should be thoroughly understood by the gas-fitter, and the subject is of considerable importance to the general public, whilst the number of gas consumers to whom the gas meter is nothing but a box of mystery is very large. Not only should the methods of testing meters be made clear, but it should also be understood that this testing is done by a public official in accordance with the provisions of the Sales of Gas Act, in which it is enacted that any meter for measuring the quantity of gas delivered to a consumer, besides being incapable of access for the purpose of tampering, and having means of sealing to prevent such fraudulent access, must not be capable of registering more than 2 per cent. fast (that is to say, 2 per cent. in favour of the gas company or supplier) or 3 per cent. slow (in favour of the purchaser). In all large centres of population an inspector is appointed, whose duty it is, on payment of a small fee, to examine any meters that may be submitted to him, and to certify whether or not they comply with the requirements of the Act. Should a meter at any time be thought to be registering incorrectly, it is in the power of either the purchaser or the seller of the gas to have the meter removed and forwarded to the nearest inspector for testing; and a certificate, duly signed by such inspector, can be obtained. If the meter is found to be correct, the parties who have claimed the examination of the meter must pay the costs of carriage and the fee; but if it is found to be incorrect, the other side must pay the costs.

The meter in the consumer's house is, as a rule, though so often found fault with, a most efficient measurer, each meter being stamped by a Government official as being only liable in the most extreme cases to the variations mentioned above.

Meters are of two kinds, known respectively as wet and dry, and the methods of testing are explained later at pp. 89-92, 95 and 96. Meanwhile it is expedient to describe first the older form, or wet meter. The course of the gas through the

wet meter is as follows:—The inlet pipe is on the front, and the gas passes down through the valve-box, which contains a conical valve with the seat fixed to a float, so that should the water in the meter fall below a certain level the valve is closed; and the same effect results from an excess of water. From the valve-box the gas passes up through the bent tube or spout into the outer casing of the drum, which is open and common to all the compartments, but sealed by the water from direct passage to the outside. The gas now enters that one compartment which has its inlet above the water, the slight pressure of the gas causing the drum to revolve so as to make a greater space for the gas, and this revolution has the effect of immersing the previously filled chamber more deeply into the water, and consequently the gas is pushed out into the case and thence to the consumer. Of course, the height of the water regulates the capacity of the compartments. Many inventions have been brought out for replacing the water lost through evaporation, some using a spoon that delivers a small quantity of water at each revolution, others having a compensating drum within the ordinary one so as to allow a certain quantity of the gas to pass back when the low level of the water has permitted too great a quantity for the amount registered to go forward. The index is controlled by a train of wheels set in motion by the revolutions of the drum, which acts by means of a screw and pinion-wheel. A consumer's wet meter, then, consists essentially of three parts. First, working partly in water, is a hollow drum or wheel, through which the gas passes, producing a rotation, the registration of which on an index indicates the quantity of gas being consumed; secondly, an arrangement for keeping the water at constant level; and thirdly, the index. The drum is divided by cross partitions into three or four chambers, into each of which the gas enters in turn, the pressure of the gas causing the drum to revolve, and the gas, from the chamber which has been filled just previously, to leave by an opening on the further side from that in which it was filled; the water forming a seal by which the gas is prevented from escaping direct into this outlet. The level of the water, which must always be above the centre of the drum, is the regulator of the quantity to be registered, as it may readily be understood that if the water fills up a portion of the chamber into which the gas is passed there will not be so much room for the gas, and therefore the meter will register faster than was

intended. To prevent this occurrence to more than a stipulated extent (2 per cent.) an overflow is provided, and as soon as the full quantity of water has been put in an overflow provides a passage for any further water which may be poured in, thus preventing the meter from registering faster than it is set for. To prevent the meter from registering slower than it is desired (3 per cent.), a valve (B, Fig. 54) is placed on the inlet, somewhat after the fashion of a ball-cock in a cistern, the valve being fixed

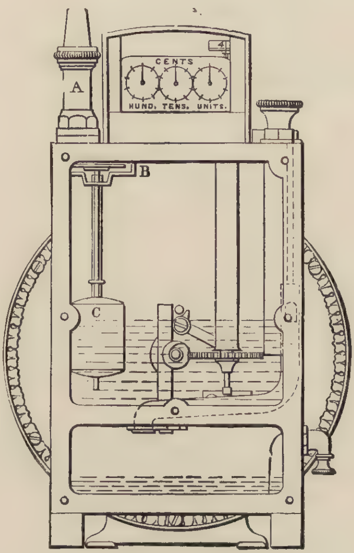


Fig. 54.—Front Elevation of Wet Meter.

upon a float C, which falls as the water grows less, from evaporation or other cause, until the valve gradually closes, and the gas can no longer pass into the meter at all.

Fig. 55, p. 86, is a cross section and Fig. 56, p. 87, a front view of a wet meter. The reference letters indicate the same parts in each figure : A A is a hollow drum which revolves in an outer casing on the axis B. The drum is divided into four sections which radiate from the axis. Each of these sections is filled in rotation with gas passing through the pipe C into a box, from which it

passes through the pipe D. E E is the water-line, and F is the gas exit pipe leading to the burners. G is a pipe with a screw cap for filling with water, H is an overflow pipe for any excess of water to run into J, whence it can be drawn through the pipe with cap K. L is a ball float which closes the valve above and stops the gas from passing when the quantity of water is too little. M is a spindle, turned by the rotation of the axle B, and

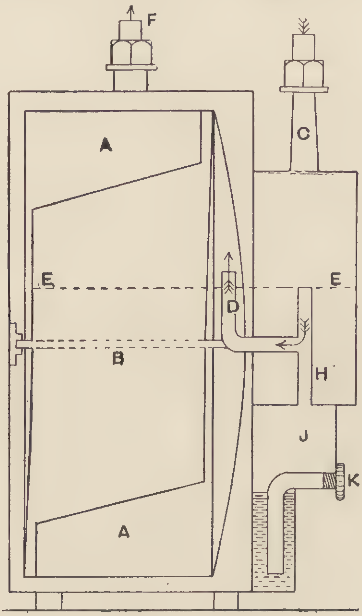


Fig. 55.—Section of Wet Meter.

connected to the dials at N. With too little or too much water in the meter, the quantity of gas passing through is not properly registered. An objection to wet meters is the liability of the water to freeze, stopping the supply of gas. Common salt has been recommended as a convenient substance for preventing the water in a wet meter from freezing, but it has the disadvantage of rusting the inside works. A little glycerine mixed with the water will generally answer the purpose. The addition of only a

small quantity of glycerine is sufficient, 2 per cent. being suggested by some, or about two tablespoonfuls for a three-light meter. It is said that the glycerine, however, has the effect of reducing the illuminating power of the gas ; but this drawback would be only temporary, as after a while the glycerine would have absorbed all the hydrocarbons from the gas which it could hold in suspension, and afterwards would not affect the illuminating

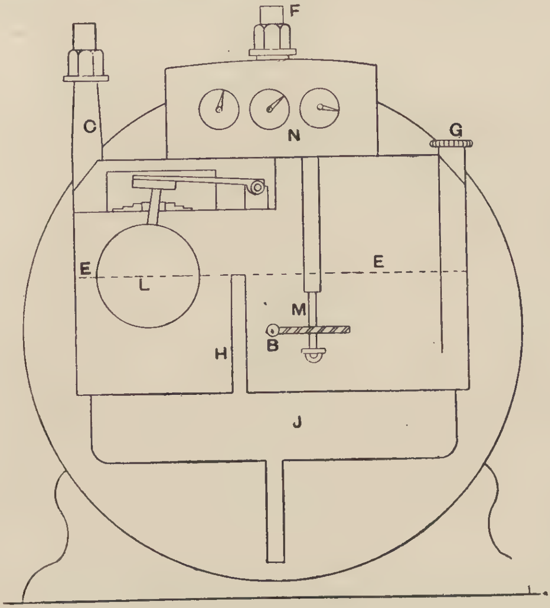


Fig. 56.—Front Elevation of Wet Meter.

power of the gas. The Royal Artillery authorities suggest the use of a mixture of methylated spirit 7 gal., distilled water $3\frac{1}{4}$ gal., mineral oil $\frac{1}{4}$ gal., and carbonate of soda 250 gr. to prevent freezing in their hydraulic jacks ; but this would probably have a still greater effect on the illuminating power of gas than would the addition of glycerine. A good plan is to enclose the meter in a large box, which may be packed with horse manure, felt, slag wool, or other low conductor of heat, on the approach of winter.

When a gas meter is actually frozen, probably the readiest means of obtaining a light is to supply the meter with warm water until the ice thaws, when the surplus water will escape by the overflow. The water should be poured all over the meter, and afterwards in through the hole which, covered with a screw plug, is generally to be found on the right-hand side of the index-box. The plug should be removed, as well as a smaller one at the bottom of the front box on the meter, either at the side or in front. The bottom hole is the outlet for the surplus water. After as much as possible of the water has run out, return both the plugs to their places. Water is sometimes carried with the gas, causing the flames at the burners to jump or flicker.

The same kind of counting apparatus is employed in both forms of meter. The initial measure of gas is the capacity of one quarter of the measuring drum in a wet meter and of one of the chambers in a dry meter (for description of dry meter, see pp. 93 to 95), so that in the case of a wet meter four measures or quarters constitute a complete revolution, and in a dry meter usually four motions constitute also a revolution. The index dials of a small gas meter up to 10-light are usually three in number; there are four circles or more on meters beyond that size. In addition to this, there is often a small circle divided into single feet, and indicating either 5 ft. or 10 ft. per revolution, used for ascertaining the capacity of the meter; it also enables the consumer to find the hourly rate of consumption of all or any part of his burners or fittings. The gas company, however, in making out their bill, take no notice of this circle. The four circles in Fig. 57 represent the indices of an ordinary gas meter. The first circle at the right hand of the dial represents 1,000 cub. ft. per revolution of the hand, the subdivisions being hundreds of feet. The pointer travels as do the hands of a clock. The second circle from the right represents 10,000 ft. per revolution of the pointer, which travels in an opposite direction to the first. The third circle represents 100,000 cub. ft. per revolution, and the pointer travels in the same direction as that of the first dial. Each pointer in succession travels in the reverse direction from that of its neighbour, and the figures on the top of the dial plate show each cubic foot of gas that passes through the meter, whether consuming or escaping. The drum of a 3-light meter (the capacity of a meter is indicated by "lights"—a light = 6 cub. ft. per hour — a term explained more fully at p. 90) is

supposed to make 144 revolutions per hour, and this works out to 18 cub. ft. per hour as the measuring capacity of the meter, thus $\cdot 125 \times 144 = 18\cdot 0$. The capacity per revolution refers to one complete revolution of the measuring arrangement of the apparatus, and this is transformed into even feet by suitable gearing, so that one complete revolution of the small circle indicates the passing of 10 cub. ft. of gas.

To take the state of a meter, commence at circle 1, and whichever number the hand has last passed will indicate hundreds. In the case illustrated it is 7 or 700. (Bear in mind that it would have to go right round to be 1,000.) In circle 2 the hand is between the 4 and 5, but, although it is nearest to the 5, it is

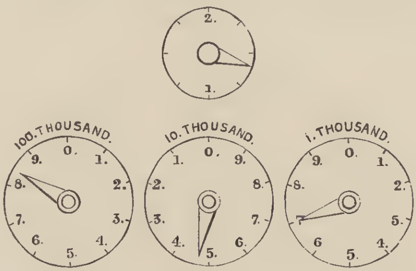


Fig. 57.—Indices for Gas Meter.

called 4, which makes it 4,700. The reason why it is called 4, and not 5, is because the hand has not reached 5, but has passed the 4 and about three-quarters, or 700, over. In circle 3, the hand is between the 8 and 9, very nearly half-way, which makes the reading 84,700. The small circle above merely indicates units, and, for reasons already explained, need not be regarded. The indices of both wet and dry meters sometimes vary slightly with different makers.

The testing of a wet meter is proceeded with as follows :—The meter is filled with water until by its running over it is shown that sufficient has been put in ; the meter is then placed on a level bench, and the gas supply, at 3-in. pressure of water, brought to it by bent pipes and connected to the inlet pipe A, Fig. 54, p. 85, by rubber tubing, the outlet being connected in a similar way to a line of gas burners, which are turned on and to which a

light is applied. When the gas has expelled all the air in the meter and pipes, a condition indicated by the burners giving a proper flame, all the burners are turned out except such a number as will allow the consumption of not more than one-twentieth part of the measuring capacity of the meter, and not less than $\frac{1}{2}$ cubic ft. per hour ; a small jet of gas is applied to all joints and parts of the meter where leaks may be anticipated, and if any show themselves they immediately take fire and are easily detected, but if none are seen the meter is said to be tight or sound. The next operation is to test the quantity of gas capable of being passed by the meter, to ensure that it is possible to obtain the amount of gas for which the meter is intended ; and this is done by passing air from a holder of special construction, graduated to a very fine degree, and verified and stamped by Government officials. It is usually of $5\frac{1}{2}$ cubic ft. or 11 cubic ft. capacity, and throws a constant pressure of $\frac{5}{10}$ in. It is then noticed what quantity is passed during, say, one minute, and this quantity multiplied by sixty gives, of course, the capacity per hour. As during this test the outlet of the meter is wide open, the amount passed should be considerably more than the size of the meter would indicate. (It may be here mentioned that meters are spoken of as for so many lights—a somewhat misleading method of indicating the size, as lights are of many different sizes, and consume very varying quantities of gas, but it should be borne in mind that a light is supposed to consume 6 cubic ft. per hour ; consequently, when a meter is called a five-light it will pass easily 30 cubic ft. per hour, and this will be useful to recollect when gas-stoves are being fixed and the size of meter desirable is wanted.) A cap with a hole in it, to restrict the passage of the gas, is fitted on to the outlet of the meter, and allows just the quantity to pass which the meter is intended for ; and if the meter be a new one, it is usual to test it before it is quite complete—that is, before the upright spindle, connecting the axle of the drum with the index, is mounted with the small leaden drum which is to be seen above the index dial in all such meters when complete. In this case a brass disc of some 3 in. in diameter is mounted in its place, this disc being carefully divided so that the revolution of the spindle can be accurately gauged. It is now easy to see whether the amount passed from the holder is being registered by the revolution of the spindle, and the percentage fast which the meter is

now showing can be easily ascertained; by passing, say, an exact cubic foot by the revolution of the disc, it will be found, if the meter be correct, that $\frac{2}{100}$ths less than a cubic foot only have passed out of the holder. If this amount is not indicated, but a less quantity only has left the holder, the water level has to be raised, and this is done in different ways. In the usual form of meter the overflow consists of a tube threaded some distance up, and screwed into the division-plate between the water space and the overflow chamber. The top of this tube forming the water level in the meter, it can screwed up or down, and fixed to its correct height by a back-nut (see Fig. 58).

In the case just mentioned the meter was measuring too fast, and therefore the water level was too high; the overflow tube would have to be screwed lower down, the back-nut being

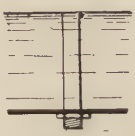


Fig. 58.

Fig. 59.

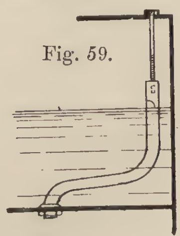


Fig. 58.—Back-nut. Fig. 59.—Enlarged View of Valve.

loosened first, and tightened when the proper level was obtained. Another form of wet meter has the overflow tube made of tin-plate, and bent so that it can be raised by a screw from the outside without damage to the pipe or the trouble of undoing the meter front to correct the position of the water-line; in fact, it is common to use a piece of plate-glass fixed to the front of the meter with putty and lashed to it by cord until the water-level has been correctly ascertained. All this is avoided by the above-mentioned arrangement, shown in Fig. 54, p. 85, and in detail at Fig. 59, in which the head of the screw is afterwards embedded in sealing-wax with an impression upon it to prevent tampering. So much suffices for the capacity at high-water level. Now the water has to be syphoned off until it is found that the valve B (Fig. 54) above the float C has closed, when water is returned to the meter until the valve is sufficiently opened to allow the full quantity of gas for which the meter is constructed to pass;

then the holder is again connected, and the comparison made between its record and that shown by the disc. If it be found that the holder registers more than 3 per cent. above that shown by the disc, the position of the valve B, Fig. 54, p. 85, has to be altered

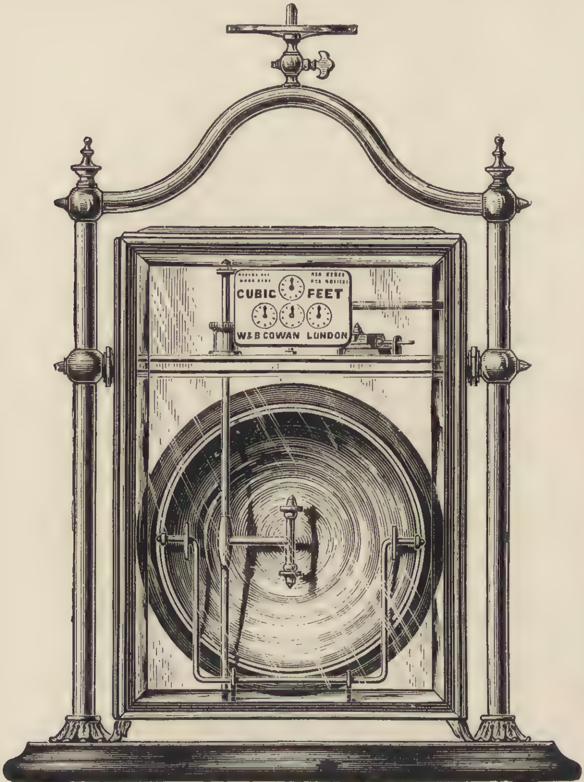


Fig. 60.—Dry Meter in Glass Case.

—raised or lowered on the float spindle by screwing it up or down, or by soldering it in a fresh position on the spindle, according as the percentage is greater or less than the 3 per cent. allowed by the Act. The meter is now ready for the official prover, who tests it at both high and low water level before certifying. When

the meter is complete and the leaden drum is fixed, it will be noticed that there are divisions and figures on it which represent cubic feet, and these have to be used instead of the brass disc.

The action of the dry meter depends upon the alternate expansion and contraction of flexible leather chambers of a definite capacity, the motion of these chambers being communi-

Fig. 61.—Side View of Dry Meter.

cated by a series of levers and cranks to the wheelwork of the index. Dry meters are made with either tinplate or cast-iron cases, and contain two or more circular measuring chambers, one on each side of a centre plate, to which they are attached. The ends of these chambers are made of a special white metal, and the sides consist of diaphragms of flexible leather, usually Persian sheepskin. These open and shut like circular bellows, and when fully extended regulate the measuring capacity of the meter. Connected to each chamber is a slide-valve, through which it is alternately filled with and emptied of gas, the move-

ment of the circular metal ends being communicated to the index by an arrangement of cranks and levers. Figs. 60 to 62 illustrate such a meter, made with a glass case, and afford very clear views of the mechanism of one of the best-known meters. Fig. 60, p. 92, gives a front view of this meter, Fig. 61, p. 93, a side view, whilst Fig. 62 gives a sectional view of the valves and passages.

The internal construction of a very similar meter is shown in the front view (Fig. 63), in which O is a tinned iron case with an

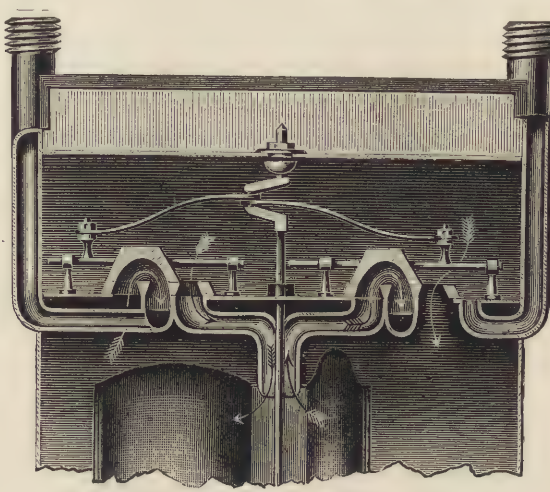


Fig. 62.—Section of Dry Meter.

upper chamber P, in which are the valves and gearing for the passage of the gas to and from the measuring chambers. These latter are in the lower part, and consist of two flat discs (one is shown at Q) of tinned iron, with flexible leather sides at R R. The back edges of the latter are fixed to a central vertical partition which divides the lower part of the meter into two. The discs and leathers act similarly to a bellows, and alternately fill and empty. As the bellows fill, the gas in the chambers in which they work is expelled; and, as the bellows empty, the chambers re-fill. The capacities of the chambers being known, the quantity of the gas passing is registered by the dials S, which are turned by gearing attached to the discs, or moving parts of

the bellows. Dry meters are now much used in preference to wet meters, as they do not require so much attention, and contain no water to freeze. They should, however, be periodically tested, as they become defective by the constant wear of the leather and the liability of the latter to become hard and brittle by age.

The principle of the dry meter is that of a pair of circular bellows into and from which the gas passes alternately: which bellows are capable of being regulated to open only to such

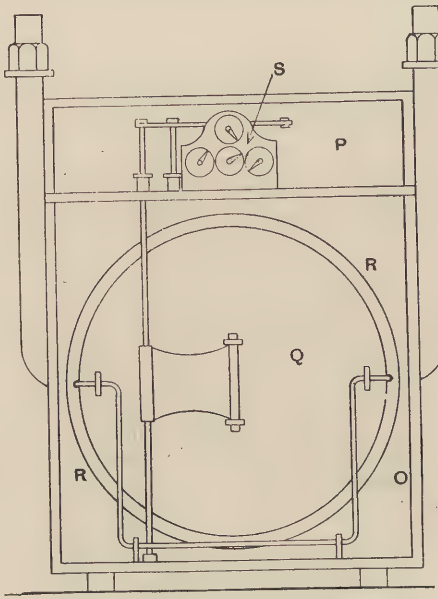


Fig. 63.—Front View of Dry Meter.

a degree at each filling that they may thus contain a certain and defined quantity; then, with a means of registering the number of times the bellows are filled and emptied, the meter becomes a recording measurer of the amount of gas passed through it.

Now, as to testing such a meter. The bellows, made of Persian sheepskins, having been tied on to the rims with wire, and thoroughly oiled with fish oils, all surplus being allowed to drip off, are fixed to the meter, which is then taken to the testing

holder, gas is passed into each of the bellows alternately, and a light is applied all round them to see if there is any leakage. If all is satisfactory, the casing-in of the meter is proceeded with; and when this is completed, and the slide-valves of white metal have been ground to fit accurately against the gratings provided, gas is again passed through the meter to ascertain if the slide-valves, which cause the gas to enter and leave the two chambers alternately, are quite tight. This is most important, as any leak here may cause jumping lights or an irregularity in the registration of the meter, p. 89. If they be found tight, the next step is to test the case for soundness in the same manner as was described for the wet meter. This proving correct, the meter is tried for correctness of registration. There being no water-line or float to these meters, they are only capable of giving one defined quantity—namely, that for which they are set; but they must nevertheless conform to the Act by not registering more than 2 per cent. fast nor more than 3 per cent. slow. If on examination they err in this respect, the extent to which the bellows is allowed to open must be regulated accordingly as the meter is registering too fast or too slow. This can be done by moving the small pin on the crank, to which the levers attached to the outside of the bellows are joined, and which causes the index of the meter to revolve by means of a worm and wheel. The longer the crank the greater distance the bellows can expand, and *vice versâ.* This being put right, the official inspector has the meter passed into his hands, when he again tests for soundness and accuracy of registration, stamping the top cover of the meter in such a way as to ensure that the registration cannot be again altered without breaking the seal. He enters the number of the meter in his book, and, if required, grants a certificate of the exact result of his test.

It will now be sufficiently clear why, as remarked on p. 59, care should be exercised in the choice of the position in which the meter should be placed; and the gas-fitter who has carefully followed the foregoing descriptions of the wet and the dry meters, will be the better able to advise when his opinion upon the subject is asked for.

CHAPTER VI.

GAS BURNERS.

While much has been written upon the principle involved in obtaining a light from gas, very little is generally known by the public as to what is required and what is the best means to adopt to secure the greatest amount of light at the least cost, and with the least vitiation of the atmosphere of the room where the light is required. Many and various improvements have been brought forward for the accomplishment of these objects; some require only a very slight alteration to the existing fittings and yet give very excellent results, while others secure a very high illuminating effect and at the same time not only remove the vitiated air which has been used to support the combustion of the flame, but at the same time carry off the air rendered useless for supporting life by the inspiration and absorption of the oxygen.

Before describing the various types of gas burners, the principle which is involved in the burning of gas may with advantage be mentioned; it has been touched upon in former chapters. Coal gas contains many very different substances; about one-half of it is hydrogen, one-third marsh gas, and perhaps one-tenth is carbon monoxide. The absolute composition of London gas, as stated by Professor Vivian B. Lewes, is given at the top of the following page.

The three gases mentioned in the statement are of no value as regards the light they will give by themselves, but they are capable of giving a great heat when ignited, and this heat is utilised for the purpose of rendering white hot the small quantity of hydro-carbons in the gas, and it is this incandescence of the very finely divided carbon particles which makes the flame luminous

Professor Lewes's statement is as follows :—

		Per cent.
Hydrogen	about	52·0
Unsaturated hydro-carbons ...	,,	3·5
Saturated hydro-carbons	,,	34·4
Carbon monoxide	,,	6·25
Nitrogen	,,	3·3
Carbon dioxide	,,	3
Oxygen	,,	·25
Sulphuretted hydrogen	,,	nil.
		100·0

When a gas burner is lighted, the rush of gas from the orifice of the burner causes a current of air to pass upon each side of the flame, and thus supply the oxygen necessary to support combustion ; the portion of the flame nearest to the burner is almost non-luminous, and is, in fact, unignited gas enclosed in a thin envelope of bright blue flame. That this is really unconsumed gas can be shown by placing the lower end of a glass tube into this portion of the flame and applying a light at the upper end, when the gas issuing from it is seen to burn with an ordinary flame. The reason that this portion of the gas is not luminous is that the quantity of oxygen which is able to get to the flame at this point is only sufficient to cause the outer portion to be in a state of incandescence. That there is solid carbon in the flame may be seen by inserting a piece of cold metal or porcelain in the white portion of the flame, which, by reducing the temperature of the carbon, becomes coated with soot upon the under side. The same effect takes place when the cold air is allowed to blow upon the surface of the flame, the excess of oxygen presented to the flame causing a cooling of the heating gases and a consequent loss of light, as the particles of carbon are not then sufficiently heated to be made white hot and to give off light, and they then allow the carbon to pass off in the form of soot and to blacken the ceilings and paint of the rooms. This is more likely to occur with high quality gas, which contains more particles of hydro-carbons ; and if there be an insufficient supply of oxygen to the flame a larger proportion of soot will be allowed to escape and settle upon the ceilings, etc. Another source of blackening of the ceilings is the nearness of the burners and

the absence of a guard (such as a coronet or bell glass) over them to deflect and spread the products of combustion over a large space. The real explanation of this effect is that aqueous vapour formed by the burning gas is condensed on the ceiling, and dust particles which are floating in the air are thereby caused to adhere to the ceilings. With high quality gases small burners should be used, so that the gas may be more thoroughly consumed.

It appears that the first burners were simply pieces of pipe with one end stopped up. In the centre of the end was drilled a small hole; and the light given off, principally owing to the shape of the flame, was very small. Then was invented the batswing burner, which has a slot cut in the dome-shaped top, and this gave a flame somewhat of the shape of a bat's wing, hence the name. Then came the union jet, which is an arrangement very generally in domestic use at the present day. It consists of a piece of brass tube plugged with a piece of steatite or porcelain with two holes in it drilled at such an angle that the two streams of gas issuing from them meet, and cause the flame of gas to spread and form a flame of horseshoe shape. One of the special points to be noticed in these burners is that the holes in them should be of comparatively large size, and the pressure of the gas when delivered from the burner reduced to the lowest point at which a firm flame can be maintained; this can be done best by means of what is known as a governor, which is in effect a self-acting valve which allows only just so much gas to pass as may be required.

Passing on to the more modern styles of burners, of which there are many patterns, such as the regenerative burners of Sugg, Wenham, Deimal, and many others, it is found that all these embody the same principle, which is to use the heat generated by the flame to heat the gas supply and the air supply so that the cooling effect of the air, which causes the blue portion of an ordinary flat flame, is considerably reduced, and the particles of carbon are rendered more rapidly incandescent, and, being heated to a greater temperature, attain greater luminosity and are kept for a longer period at this white heat.

The earliest arrangement of such a burner was invented in 1854 by a Rev. Mr. Bowditch; and his burner consisted of an argand with two chimneys, one outside the other, the air supply to the flame having to pass down between the two glasses, and so to become heated before it was led to the bottom of the burner.

This answered very well, but the breakage of the chimney glasses was a considerable expense, and debarred many from adopting the system. This trouble is quite overcome in the modern regenerative burners, as the chimneys are made of metal and the burner is inverted, so that the flame is spread outwards instead of, as in the argand burner, upwards. The regenerative burner gives a light having four times the illuminating power of the flat-flame burner.

With the incandescent burners, quite a modern invention, the principle of admitting air to mix with the gas before lighting is employed as in the Bunsen heating burner, and this, while taking away the luminosity of the flame, causes it to give off a much greater amount of heat, this heat being utilised to render a mantle of rare earths incandescent or white hot. These mantles are made conical in shape, and when made white hot emit a most pleasing white light, which is about five or six times more intense than that given off by the ordinary flat flame burner.

With a properly arranged ventilating regenerative burner, consuming 20 cubic feet of gas per hour, and properly fitted, not only can all its own products of combustion be removed, but also the air vitiated by breathing can be removed at the rate of more than 5,000 cubic feet per hour from the upper part of the room.

The comparative quantity of air vitiated by different illuminants giving the same amount of light is shown by the following table :—

Gas burnt in union jets	1
Lamp burning sperm oil	1·6
„ „ paraffin oil	2·25
Sperm candles	2·65
Tallow candles	4·35

From this table it will be seen that paraffin lamps use up more than twice the amount of the oxygen of the air that gas does, while tallow candles use more than four times the amount.

Professor Vivian B. Lewes found that, for a light of thirty-two candle-power, sperm candles would vitiate as much air as would be required by about twenty-two adult persons; paraffin oil lamps as much as fifteen adults; while London gas varied from an amount of air required for nine and a half adults when a

batswing burner was used, to eight and a half when an argand burner was used, and to two and a half when a regenerative burner—in which the products of combustion were allowed to pass into the air of the room—was employed. In these experiments not only was the quantity of oxygen consumed taken into consideration, but carbon dioxide and the water vapour were all taken account of.

Special attention must be directed to the necessity of having burners suitable to the quality of gas which is being used. It may be taken as a fairly general rule that the higher the illuminating power of the gas the smaller the burner should be. With London sixteen candle-power gas, the 5-ft. per hour, or No. 5 union jet, is very suitable, but with a sixty candle-power gas a No. 0 or No. 00 burner is much more efficient. With unsuitable burners, not only blackening of the ceilings, but a far lower state of efficiency as regards the illuminating power of the light obtained from a given quantity of gas will result.

The effect of using bad burners is primarily that the light capable of being developed from the consumption of a definite quantity of gas is not obtained: consequently more gas is burnt than necessity requires; in other words, gas is wasted, and with imperfect combustion, deleterious products are given off, vitiating the atmosphere and endangering health.

That the burners which are most economical in gas consumption are the most expensive at first cost is certainly the case to some extent; but the amount of the saving effected by their use quickly repays the first cost, and thereafter the money saved goes directly into the pocket of the user of the burner. The incandescent burner is the most economical burner that is at present known, and where gas is at a high price it is a very distinct advantage, as the quantity of gas required for a given amount of light is only about one-fifth of that used with the ordinary burner. The regenerative burners come next in point of economy, and these are of many patterns, all very much on an equality. Then comes the argand burner, which is superior to the union jet or flat-flame burner; but in all these an arrangement known as a governor is generally to be found, by which is regulated the quantity of gas that can find its way to the point of ignition, and, if only just sufficient is allowed to pass so that none is wasted, gas is economised. These governors are also made for use with the ordinary flat-flame burner.

As has been said, the principal gas burners now in use are the flat-flame, argand, regenerative, and incandescent. Flat-flame burners embrace the union jet, or fishtail, and the batswing. In the union jet or fishtail the gas issues through two apertures in a steatite plate inserted in the top of a cylindrical brass tube, screwed at its lower end for the purpose of attaching to a gas-bracket. The holes in the steatite tip through which the gas issues are inclined towards each other at an angle, so that the gas issues in two streams which unite into one flat flame at right angles to a plane passing through the two holes. One of the reasons of the adoption of steatite for the tip of the gas burner was the fact that it required a very high heat to harm it. Steatite is a natural stone found in various parts of the world, principally in Germany. Chemically it is a double silicate of magnesium, and a substitute for the natural substance may be obtained by mixing silicate of magnesium and silicate of potash. Natural steatite is of a very fine grain, and softer than ivory ; it admits of being worked to a very fine polish, but after it has been burned in a kiln it becomes harder than the hardest steel, and will resist a very high temperature—say 2,000° F. (1,093° C.). In forming the steatite into burner tips, the material is finely powdered, moistened with water, and kneaded into a plastic condition, after which it is moulded to the requisite shape and finally burnt to harden it. The diameter of the orifices in the steatite tip, through which the gas issues, differs in size, the aim being in each case to produce a flame of a thickness suited to the quality of the gas the burner is intended to consume.

The batswing burner resembles the fishtail or union in its general features, but differs in the manner in which the gas issues from it. In this form of burner the hollow tip is made dome-shaped and has a narrow slit cut across it and extending some little distance down. The slit varies in width to suit different qualities of gas. The batswing burner requires less pressure than the union jet, with the result that the gas issues with less force, so that the flame produced in burners of this class is not so stiff as that obtained with a union burner. Consequently it is necessary to employ globes with burners of this description in order to protect them from draught, which would cause them to flicker and smoke.

Sugg's table-top burners (Figs. 73 and 74, p. 104) are prevented from flickering by providing a rim just below the steatite tip,

while the large batswing burners employed in street gas lamps have side wings, or lugs, for the same purpose.

The gas consumption in cubic feet per hour, and the illuminating power in candles of Bray's flat-flame burners, the gas being supplied under a pressure of ten-tenths, or one inch, are shown in the table below. Some of the figures may appear inconsistent, but all are based on tests made by Mr. T. Fairley, at the instance of the Leeds Corporation.

Bray's Burners.	*Gas Consumption.*				*Illuminating Power.*			
	No. 1.	*No. 3.*	*No. 5.*	*No. 7.*	*No. 1.*	*No. 3.*	*No. 5.*	*No. 7.*
Regulation Union Jet	3·9	4·8	7·97	8·65	4·72	6·9	20	25
Special Union Jet ...	4·02	4·9	6·67	8·05	8·3	15·6	24·4	30·2
Regulator Slit Union	4·8	6·37	8·14	9·04	14	20·2	28·4	37·2
Special Slit Union ...	3·53	4·61	6·37	8·6	10·2	16·4	23·4	33·4
Regulator Batswing...	4·26	5·64	6·93	10	10	16·6	20·4	39·8
Special Batswing	3·86	5·25	5·85	8·72	13·2	20·4	22·6	38

Whilst it is thought advisable to illustrate the better-known flat-flame burners now in use, limitations of space will not allow a detailed description of them. In most cases, their construction is simplicity itself, and the illustrations, taken with the principles just set forth, should provide sufficient explanation.

Dealing first with union or fishtail burners, Fig. 64 shows Bray's ordinary burner; Figs. 65 and 66, Bray's special unions; Figs. 67 and 68, Bray's slit-unions, which outwardly resemble batswing burners; Figs. 65 and 68 show burners screwed for supporting the gas globe holder. Of regulator union burners, Bray's slit-union is shown by Fig. 69; Bray's adjustable union burner, shown by Fig. 70, is in two parts, and by substituting for the lower tip one larger or smaller, the pressure of the gas may be regulated as required; thus Fig. 70 represents a No. 3 lower tip in a No. 6 upper tip. Hawkins and Barton's governor union burner is shown by Fig. 71.

Batswing burners are of many makes; Bray's is illustrated by Fig. 72. Sugg's well-known table-top burners are shown by Figs. 73 and 74. Falk, Stadelmann and Co. make and sell a variety of batswings, among them being the "Comet" burners, Figs. 75 and 76, the "Veritas" burner, Fig. 77, and the duplex

Fig. 64.

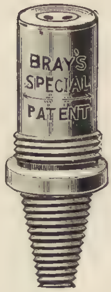


Fig. 65.

Fig. 66.

Fig. 67.

Fig. 68.

Fig. 69.

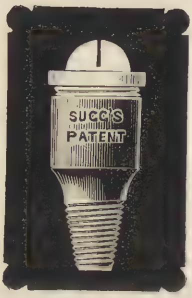


Fig. 73

Fig. 70.


Fig. 74.


Fig. 71.

Fig. 72.

Figs. 64 to 70.—Bray's Union Burners. Fig. 71.—Governor Union Burner. Fig. 72. — Bray's Batswing Burner. Figs. 73 and 74.—Sugg's Table-top Burners. Figs. 75 and 76. — Comet Burners.

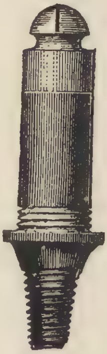


Fig. 75.

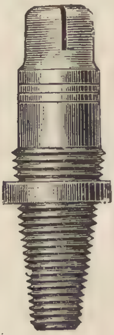


Fig. 76.

Fig. 77.

Fig. 78.

Fig. 79.

Fig. 80

Fig. 81.

Fig. 83.

Fig. 82.

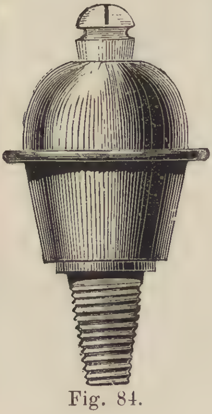


Fig. 84.

Fig. 77.—"Veritas" Burner. Fig. 78.—Duplex Batswing Burner. Fig. 79.—Bray's Adjustable Burner. Fig. 80.—Goodson's Burner.

Fig. 81.—Peebles' Male Governor Burner. Fig. 82.—Peebles' Female Governor Burner. Fig. 83.—Hawkin's and Barton's Governor Burner. Fig. 84.—Victoria or Ellis Regulator Burner.

Fig. 86.

Fig. 85.

Fig. 87.

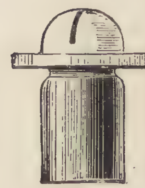


Fig. 88.

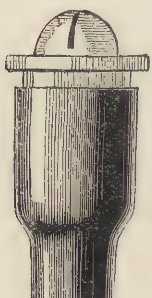


Fig. 89.

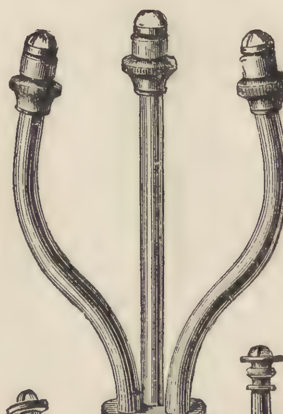


Fig. 90.

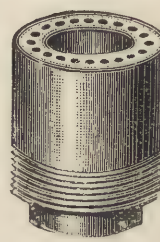


Fig. 93.

Fig. 92.

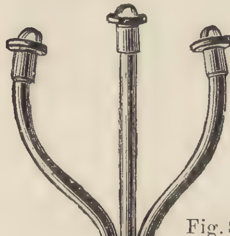


Fig. 91.

Fig. 85.—Sugg's Governor Burner. Fig. 86.—Bray's Street Burner. Figs. 87 to 89.—Falk, Stadelmann and Co.'s Street Burners. Fig. 90.—Combination Street Governor Burner. Fig. 91.—Tripod Street Burner. Fig. 92.—Descending Cluster Street Burner. Fig. 93.—Argand Burner.

batswing, Fig. 78. Of regulator batswing burners may be mentioned Bray's adjustable burner, Fig. 79 (constructed on the same principle as is the union jet, Fig. 70). Goodson's patent governor burner is shown by Fig. 80, Peebles' male and female governor burners respectively by Figs. 81 and 82, the former being in section, and Hawkins and Barton's governor batswing

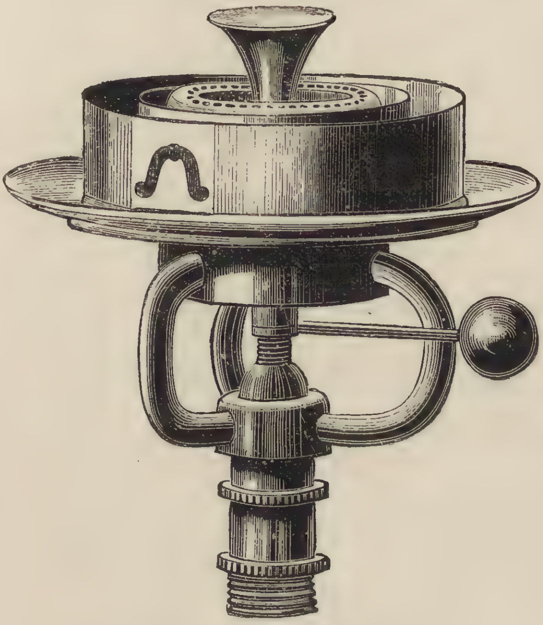


Fig. 94.—Imperator Argand Burner.

burner by Fig. 83. The "Victoria" or "Ellis" burner, illustrated by Fig. 84, has a regulator inside the gas chamber. Sugg's governor burner having a steatite float is shown by Fig. 85.

Burners for street lighting are, of course, larger than those for domestic use. Bray's "Standard" burner for street lighting is illustrated by Fig. 86; street burners sold by Falk, Stadelmann and Co. are shown by Figs. 87 to 89. Fig. 90 shows Goodson's

combination street governor. A tripod burner without a governor is shown by Fig. 91, and a descending cluster by Fig. 92; all the street burners mentioned above are of the batswing type.

The argand burner differs from the flat-flame burner principally in the manner in which the burner obtains its air. This is by a glass chimney, and air is also directed by a special contrivance on to the flame. In the argand burner gas is conveyed into the interior of the hollow ring, the steatite top being perforated on its upper surface with a number of holes for the emission of gas (see Fig. 93). Through these holes the gas issues in a series of jets which immediately coalesce to form one cylindrical sheet of flame. Surrounding the burner is a glass chimney, supported on a brass gallery connected with the lower portion of the burner. The chimney serves to shield the burner from draughts of air, and also to draw up on to the surface of the flame the air necessary for its proper and complete combustion; a small metallic cone placed between the chimney and the burner orifices also assists the action of the chimney by directing the air supply upon the surface of the flame. Fig. 94 illustrates the "Imperator" form of argand burner.

The argand burner is constructed in such a manner that the combined sectional area of the tubes which supply gas to the hollow ring is less than the aggregate area of the holes in the burner through which the gas issues, the result being that the gas issues from the burner at a considerably less pressure than that at which it enters.

The regenerative system lends itself admirably to purposes of ventilation, as by its use a room can be freed from any obnoxious vapours, and fresh air, warmed if desired, can be drawn in. Again, the products of combustion need no longer vitiate the atmosphere in the room which is being lighted, as these can be carried off direct into the open air. The methods adopted for this purpose will be described in the following pages.

It might be well to point out that with the incandescent gas burner the necessity for removing the products of combustion is considerably lessened, owing partly to the diminished quantity of gas used, and partly to the more perfect combustion of the gas and a lesser generation of heat. The incandescent burner is free from the objection to the regenerative system in that all the reflective power of the ceiling is brought into use. Its construction and use form the subject of Chapter VII., pp. 119—126.

In regenerative burners the waste products of combustion from the flame are employed to raise the temperature of the gas before it is ignited, and also of the air necessary for the combustion of the gas. This not only results in an increased efficiency, but also in a great improvement in the quality of the light, which, being emitted by incandescent carbon at a higher temperature than with open-flame burners, is much whiter and more brilliant.

The principles set forth above are utilised in regenerative burners in the following manner. The burner itself, which is circular, somewhat resembles an inverted argand without its chimney, and is arranged so that the flame is enclosed in an air-tight glass shade and is prevented from coming into contact with the outside air. The flame is deflected by a plate of porcelain, and passes in an upward direction towards the interior of the burner. The gas and air flow through separate pipes to supply the burner, and they are heated by the waste products of combustion as they pass through a series of pipes, or flues, the walls of which are in contact with the heated products. The method in which this contact is brought about is the chief difference in the various patented burners of the regenerative class.

The advantages of the regenerative system of improving the illuminating power of gas are well known. In practice it can be said that, by means of the regenerative system, an equal quantity of light can be obtained by about one-third the consumption effected by the flat-flame burners in the usual type of fitting; while for a given consumption it is safe to reckon upon almost treble the light from regenerative lamps as from ordinary burners. It must, however, be borne in mind that there are certain inconveniences connected both with the fitting and with the maintenance of regenerative lamps, and that there is also some risk of failure arising from bad fitting.

The principle is very simple. All that has to be done is to exclude cold air from contact with the flame, and to supply instead a stream of heated air, warmed by the waste heat generated by the flame itself; then, by turning the argand burner upside down, a double or treble duty is got from the gas. If an equal quantity of light is obtained from less than half the quantity of gas, it follows that less vitiation of the atmosphere results; and further, when the source of light and point of consumption of the gas is very much nearer the ceiling, the room must

be healthier to a corresponding degree. Thus much may be claimed for the ordinary non-ventilating regenerative lamp, which discharges the products of combustion near the ceiling. The funnel-shaped top to these lamps leads to the inference that a greater quantity of the deleterious products of combustion is given off through that top, while the hygienic consequences of the fact that the quantity of gas used is far less than in the case of the ordinary burners are quite ignored. It is true that the heat of the air near to the lamp itself will probably be greater than it would within the same distance of a gasalier; but the objection often urged against gas-lighted rooms refers less to their thermometric heat than to the vitiation of the atmosphere and the consequent feeling of oppression; and this evil is not present when a regenerative lamp is employed.

The incandescent burners, with the greatly increased duty per cubic foot of gas which they afford, have rendered the sale of the ordinary regenerative lamp comparatively small; still, the advantage of the ventilating type of lamp is great. So efficient is it in this respect, that plants and flowers may with safety be left in rooms where it is in use; whereas gas burned in the ordinary way has a marked injurious effect.

Sugg's "Sandringham" regenerative lamp, a handsome fixture, is illustrated by Fig. 95, and from a sectional view given at the top may be gleaned the principle that governs the less elaborate lamps as well as the one illustrated. There are many obstacles to absolute efficiency in the ventilating regenerative system. For instance, the difficulty of getting access into the proper chimney; and there is always uncertainty as to securing a good up-draught. When joists and angles prevent connection with the chimney of the room in which the regenerative lamp is to be fixed, flue pipes are sometimes led into an adjoining chimney; but to do this is to court failure, or at best the success will be accidental. A point which is often overlooked is the securing of an efficient fresh-air inlet to the room, which is as essential as a good outlet. So uncertain is the result of connecting ventilating lamp flue-pipes with the chimney flues that, where possible, it seems better to carry separate flue-pipes to discharge above the roof. But it is always necessary to pack non-conductive material round the flue-pipes their entire length, and to use an exhaust ventilator, double-cased and packed in the same way, otherwise the best ventilator will, under certain conditions, act as a refrigerator, and prevent

Fig. 95.—Sandringham Regenerative Gas Lamp.

the exit of the heavier gas. When it is impossible to carry a flue direct from each lamp to the top of the building without running into the ordinary chimney, the object may be effected by cutting out a hole in the chimney, and putting a course of bricks, preferably with a bevelled edge to prevent the accumulation of soot, so placed as to project, say, 1 in. or $1\frac{1}{2}$ in. into the chimney space, and thus reduce the area of the flue immediately below the entrance made for the introduction of the flue-pipe from the lamp. By this method the amount of draught available for the coal fire below is somewhat reduced, it is true, but not to such an extent as to appreciably affect the proper burning of the stove; the flue, if used solely for a gas lamp, would be sufficiently large if it were only about 3 in. or 4 in. diameter.

Too much stress cannot be laid on the necessity of carefully packing with either asbestos or slag wool, or some other suitable non-conductor of heat, the flue pipes carrying the products of gas flame, more especially when these flue pipes are in close proximity to timber. It must be remembered that, although the heat given off by the pipes is not sufficient in the usual way to set fire to any woodwork, still, in time soot may accumulate and get heated; and, in any case, a continuance of the temperature that occurs near the flue-pipes is exceedingly hurtful to timber, causing it to lose its nature and to decay. A good plan of preventing any trouble in this way is to coat the pipe with non-conducting composition and then fit a sheet-iron pipe over this composition; or the smaller pipe can be placed inside the larger, and the intermediate space packed with slag wool before it is placed in position between the ceiling and floor. An efficient ventilator cowl must be used, so that a down-draught cannot possibly occur. There is a considerable choice of these cowls, but with any of them the recommendation made previously as to packing the outside of the ventilator with some non-conducting composition must be followed.

The ventilating tubes should be so laid that any moisture from condensation may find its way to a drip-box. Glazed earthenware soil pipes for flues are good and lasting, and these may be carried up inside the chimney flue to the top; they will be kept warm by the gases from the coal fires, and so assist in the ventilation. But the necessity for a drip-box for the condensation water must not be overlooked.

The flue should be of such a size that it will carry off just as

much air as the lamp will remove—no more and no less; and to do this the height of the flue, the diameter, the number of curves, and the size and position of the room chimney in respect to the lamp's position, and again the quantity of the fresh air which is to be admitted into the room, should all be taken into consideration. If sufficient fresh air is not admitted to supply both the coal-fire chimney and the lamp, the probability is that the lamp-flue will be called upon to supply the deficiency, a down-draught will ensue, and then the lamp will prove an utter failure.

For the supply of fresh air to a ventilating regenerative lamp there is nothing more simple nor more effective than the Tobin tube, which can be fitted up in any room at little expense. This consists of a rectangular tube, say 9 in. by 3 in. or 4 in., fixed against an inside wall, reaching to about 6 ft. above the floor, with a hinged lid on top, and through the wall at the floor level an opening to the bottom of the tube. By this air is drawn in and let out above the heads of the occupants of the room, and draughts are avoided. The tube can be made to fit in the corner of a room, and need then only consist of a flat board fixed in the angle.

It has been found that a vertical flue, 6 in. diameter, 12 ft. long, when a gas burner consuming only 1 cub. ft. per hour is burning inside it, will remove 2,460 cub. ft. of air per hour. Thus it will be seen that a cubic foot of gas in a ventilating shaft can be made to remove more than 2,400 times its own bulk of air, and the gas which is consumed in rooms might thus become a most valuable adjunct to the ordinary means of ventilation, and improve sanitary conditions. If each room in which gas is used were connected to a flue in which a gas-burner could be kept alight, the products of combustion arising from the use of the gas might be carried away as rapidly as made, and with them might be taken the vitiated atmosphere exhaled from the lungs; the flue should be made of such a size as to allow of a complete change in the air of the room every ten minutes. Thus, given ten rooms, each 12 ft. by 12 ft. by 10 ft., of which it was desired that the air should be changed entirely every ten minutes: this could be done with the use of some 36 cub. ft. of gas per hour. But this is far more than need be allowed in most cases, and it would probably suffice to allow for only one-third of the air to be changed once every twenty minutes, which would require about 6 cub. ft. of gas. By the consumption of this quantity, absolutely fresh air might be obtained in the rooms of a ten-roomed house.

The atmospheric and the illuminating flame appear to have the same effect in all cases where a large quantity of air has to be heated to a low temperature. The maximum consumption of gas in a ventilating flue should not exceed 5 cub. ft. per hour for each circular foot area of section. The remarks previously made with regard to the necessity of admitting fresh air to equal the quantity taken out apply in like manner in this case, and the object may be effected by the same means.

The gas consumption and illuminating power of Sugg's regenerative lamps are stated by the makers to be as follows :—

Size.	*Hourly Consumption of 16-candle-power gas.*	*Illuminating Power with Reflector.*
—	3 cubic feet	28 candles
—	4 ,, ,,	37 ,,
1	6 ,, ,,	72 ,,
2	10 ,, ,,	150 ,,
3	15 ,, ,,	240 ,,
4	20 ,, ,,	320 ,,

The following table gives the duty obtainable from burners of different types when burning 16-candle coal gas :—

Burner.	*Light Obtained per Cubic Foot of 16-candle Gas Consumed.*
	Candle Units.
Incandescent	14·9
Regenerative	10·0
Standard argand	3·2
Ordinary argand	2·9
Flat-flame, No. 7	2·44
,, ,, 6	2·15
,, ,, 5	1·87
,, ,, 4	1·74
,, ,, 3	1·63
,, ,, 2	1·22
,, ,, 1	0·85
,, ,, 0	0·59

Following these remarks on the ventilating regenerative burners, it is appropriate that Strode & Co.'s "Sun Burner" should receive consideration. This burner was introduced many years ago, but the patented gas burner and ventilator now on the

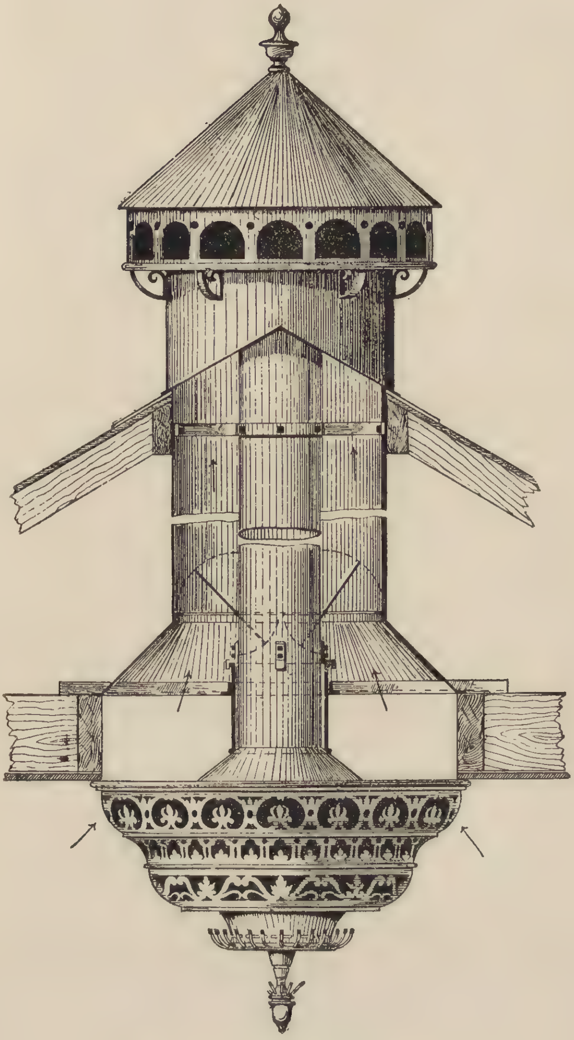


Fig. 96.—Strode's Sun Burner.

market is a great improvement on the original invention. By an arrangement of cones, heated air is introduced to support the combustion of the gas, thus obtaining high illuminating power and good ventilation of the apartment, the whole of the products of combustion being carried off through the perforations which surround the Sun burner cones; a flue running through the ceiling is connected to the Sun burner, and discharges the undesired gases. Thus the inside atmosphere is not vitiated by the burning gas, but an efficient system of ventilation is provided. Of course, the very utmost attention must be given to the arrangement and putting in of the flue, as on the efficiency of this rest the illuminating power obtained and the working of the ventilating system. Fig. 96, p. 115, illustrates a pattern of Strode's Sun burner fitted with an outer ventilating shaft and an extract wind-guard. The sizes and principal dimensions of the new patent Sun burners are given in the following short table, compiled from particulars furnished by the makers:—

Number of Jets.	*Extreme Diameter of Sun burner.*	*Diameter of Inner Cone.*	*Diameter of Outside Case.*	*Diameter of Flue Pipe.*	*Illuminating Power in Candles.*	*Diameter of Gas Supply Pipe.*
6	16 in.	$10\frac{1}{4}$ in.	16 in.	5 in.	144	$\frac{3}{8}$ in.
9	24 in.	$14\frac{1}{4}$ in.	24 in.	6 in.	220	$\frac{1}{2}$ in.
15	29 in.	$18\frac{1}{2}$ in.	29 in.	10 in.	360	$\frac{1}{2}$ in.
32	38 in.	27 in.	38 in.	12 in.	800	1 in.
41	48 in.	34 in.	48 in.	14 in.	1,000	$1\frac{1}{4}$ in.
65	58 in.	42 in.	58 in.	16 in.	1,500	$1\frac{1}{2}$ in.

The principle of the albo-carbon light depends upon the carburetting of the gas with the vapour of a hydro-carbon obtained from a solid substance, which may be naphthalene. Naphthalene is obtained from coal-tar, and has the formula $C_{12}H_8$; it melts at 175° F., and boils at 410° F., but when it is raised to a temperature of 212° F. a hydro-carbon vapour is given off sufficient to saturate the gas with its full amount of carburetting material. Fig. 97 is a sectional view of a common form of albo-carbon fitting. In most of these fittings is an aperture for charging the vessel with the small fluted cylinders; the aperture is closed by a screwed plug. The gas-supply pipe in the interior of the vessel is carried sufficiently high to be above

the melted naphthalene, and is bent down, or a hole is made in the under side of the pipe, so that the gas shall blow directly on the surface of the carburetting material. The outlet pipe is usually taken from near the top of the vessel, and is bent downwards 4 in. or 5 in., and again bent so that a burner may be fixed in a vertical position. From one side of the vessel, and immediately above this burner, projects a blade of copper which, being heated by the flame of the burner when alight, conducts an amount of heat to the body of the vessel sufficient to vaporise the naphthalene ; so

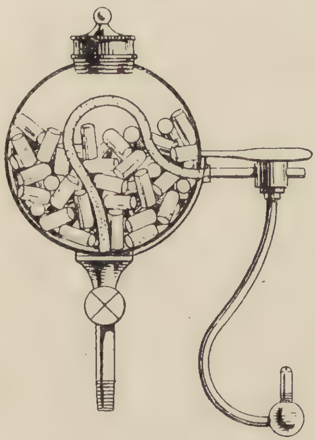


Fig. 97.

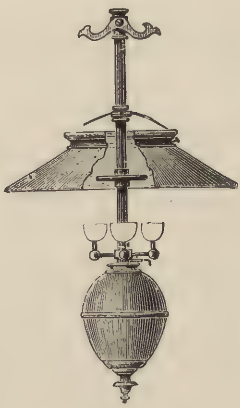


Fig. 98.

Fig. 97.—Section of Albo-carbon Gas Burner. Fig. 98.—Fitted Albo-carbon Gas Burner.

that the flame of the burner performs the work of vaporising the hydro-carbon for its own enrichment. When the gas is first lighted, the material in the vessel is in the solid form, and it requires several minutes before the effect of the carburation is seen ; but gradually the light assumes a peculiar brilliancy, and the illuminating power of the gas is raised from eighteen or twenty to about thirty-seven candles. The albo-carbon gas-light is adaptable to various ways of fitting ; for instance, in Fig. 98 the burners are arranged in a circle above the carburetting chamber instead of being below it.

The shape of the gas globe has a great effect upon the amount

of light given by an ordinary burner, either union jet or batswing. For many years Mr. Sugg has been showing the necessity of having a large opening at the bottom of globes in place of the restricted space which until recently was thought desirable. Now, the old-fashioned pine moon and open-top globe is falling into deserved disuse. The advantages of the more modern type are many, among the foremost being the fact that the light from the burner can pass unrestricted down upon that portion of the room which requires the greatest amount of light, and the upper portion of the globe forms an excellent reflector to aid in the diffusion of light downwards. As in most cases the gasalier is fixed in the centre of the room over a table, it is generally required that the light shall be greater immediately underneath the burner than in the remaining portion of the room. Another advantage is that a sufficient amount of oxygen is permitted to pass into the globe to allow of complete combustion of the gas without unnecessary draught, which would cause the flame to flicker and take a form in which the perfect combustion of the gas would be impossible. This is one respect in which the flat-flame differs from the argand, the latter requiring a draught to cause a perfect flame. Some time back an invention for improving the light from a flat-flame burner when used with the ordinary globe was brought out by a Mr. Spencer, who designed and patented a modification of the old-fashioned corona, upon which he placed a second cap, which was movable, and which could be made to open or close the apertures in the corona proper, through which the products of combustion passed. The cause of the improved lighting effect was no doubt the warming of the air during its prolonged contact with the heated globe.

The respective amounts of light obscured by the different kinds of globes ordinarily in use have been stated thus :—

Clear glass globe	obscures	about	12	per cent.
Glass with slightly ground flowers	,,	,,	24	,,
Globes of about usual pattern	,,	,,	35	,,
Globes ground all over ...	,,	,,	43	,
Opal globes	,,	,,	60	,,
Opal globes painted	,,	,,	64	,,

CHAPTER VII.

INCANDESCENT GAS BURNERS.

ALL gas burners that emit light have as much claim to the term "incandescent" as have those combinations of Bunsen burner and mantle which now alone are known by that name. The "incandescent" gas burner differs from any burner described in the previous chapter in this respect—that in the ordinary burner the light emitted is due to the raising to incandescence of the carbon particles of the gas itself, whilst in what is known as the "incandescent" burner the gas is used merely as a heating agent to raise certain oxides of the rare earths to incandescence. The incandescent burner consists of two portions, the burner itself and a cotton hood or mantle which, in the case of the Welsbach mantle, has been dipped in a solution of the oxides of rare earths—98 per cent. of thoria to 2 per cent. of ceria. On burning away the cotton, the oxides remain, and retain the shape of the original mantle. This is then supported over a Bunsen burner which, when the gas is lit, fills the body of the mantle with flame, producing incandescence on its surface, and causing it to give out a brilliant bluish-white light. The mantles are about 3 in. long, 1 in. in diameter at the bottom, and are somewhat conical in shape. Across the upper end of the mantle a thick loop of the material stretches; this is for the purpose of supporting the mantle when in use on the fork of a thin fireclay prop, which passes up the long axis of the mantle and fits into a cavity in the central conical-headed rod of the burner. A chimney, 2 in. in diameter externally, and about 8 in. long, fits over the mouth of the upper end of the burner, which is provided with a contrivance for diminishing the risk of lighting back. The ordinary form of incandescent burner is arranged for a gas consumption of about $3\frac{3}{4}$ cub. ft. per hour at a pressure of 1 in.; the pressure at which the gas is burnt is a most

important factor in the results obtainable from this type of burner. The pressure should never be less than 1 in.

In manufacturing the mantles, ordinary cotton is knitted in a machine into a cylindrical form, and, to free it from impurities, it is washed in a solution of hydrochloric acid and ammonia. It is then placed in a 14-per-cent. solution of the metallic oxides of some rare earths ; thoria is usually the basis of the light-giving properties. The mantles are squeezed until only sufficient liquid is left upon them to soak into all the pores, and are then left to dry. The upper ends are then sewn so that the mantle may be hung up. On considerable heat being applied, the cotton fabric is burnt away. The mantles are very fragile, and so, in order to ensure their safety in transport, they are dipped in a solution of collodion, which has the effect of giving them the necessary stiffness and toughness to enable them to withstand ordinary handling. Before the gas is lit, but whilst the new mantle is in position, this stiffening solution is burnt off by means of a spirit torch ; tapers or matches deposit soot on the mantle and chimney.

In the 1885 and 1886 patents granted to Welsbach, prescriptions for the mantles are given as in the table on the next page. The other particulars there tabulated are the results of subsequent experiments.

In the table given on p. 122, Professor Lewes has brought together the oxides which have been used in the manufacture of incandescent mantles, and his results show the amount of light emitted by each under the conditions existing in the mantles.

The Welsbach incandescent burner is illustrated by Fig. 99, p. 123. As before explained, it consists of a Bunsen burner in which air and gas are admixed before the flame-point is reached, forming a flame of very little illuminating power but of great heat. This burner should be tightly screwed upon the gas fitting, either bracket or pendant, the small cardboard washer being put on first to make the joint tight. The Bunsen burner, when fixed, must be absolutely plumb, otherwise the flame will not be of the proper shape, and the mantle, being unequally heated, will in a short time break up. The lowest pressure at which the incandescent gas burners work well is $\frac{8}{10}$ in. of water, but as a general rule 1-in. pressure is about the best, and this of course should be measured at night when the lights are likely to be most in use. If the screw upon the Bunsen burner tube is too small for that on the fitting, a double screw-piece called an

adapter which is supplied with each burner, should be fixed with the cone-shaped end into the fitting. A disc is also supplied; this is intended to prevent lighting back in the Bunsen tube. "Lighting back" is the term used for the lighting of the

WELSBACH 1885 PATENT.

Oxide.		Percentage Composition.	Cubic Feet of Gas Consumed.	Illuminating Power in Candles.	Candle-power per Cubic Foot of Gas.
I.	Zirconia ...	60	5·4	12·9	2·4
	Lanthania ...	20			
	Yttria ...	20			
II.	Zirconia ...	50	5·5	9·4	1·7
	Lanthania ...	50			

WELSBACH 1886 PATENT.

Oxide.		Percentage Composition.	Cubic Feet of Gas Consumed.	Illuminating Power in Candles.	Candle-power per Cubic Foot of Gas.
I.	Thoria ...	60	4·4	9·0	2·0
	Magnesia ...	40			
II.	Thoria ...	33·3	4·5	15·0	3·3
	Zirconia ...	33·3			
	Yttria ...	33·3			
III.	Thoria ...	30	4·7	12·2	2·5
	Zirconia ...	30			
	Lanthania ...	40			
IV.	Thoria ...	40	4·5	12·2	2·7
	Magnesia ...	20			
	Lanthania ...	40			
V.	Thoria ...	60	4·0	3·6	0·9
	Magnesia ...	20			
	Alumina ...	20			

small inner gas-supplying tube before the admixture with the air has taken place; lighting back heats the fittings unnecessarily and causes a disagreeable smell. When lighting back happens the gas should be turned out, and in a few seconds it can be

re-lighted. The next portion to fix is the gallery, which carries both the mantle and the chimney. It is as well now to light up the gas and find out if the fitting is upright and the flame correct in every particular—a very important point. The correct flame is of a clear reddish colour, about 4 in. high, and should crackle and bubble. If the flame does not reach this height when the gas is fully turned on, enlarge the gas holes at the top of the gas-supplying tube with a broach or fine reamer; make the enlargement from the same direction as that in which the gas enters. If, on the other hand, the gas-flame be too large, the gas-supplying holes should be burred over until only $3\frac{1}{2}$ cub. ft. of gas will pass

PROFESSOR LEWES'S TABLE.

Group.	*Oxide.*		Candles per Cubic Foot of Gas. *Pure Oxide.*	Candles per Cubic Foot of Gas. *Commercial Oxide.*
Metals ...		Zirconia	1·5	3·1
		Thoria	0·5	6·0
Earth Metals	Cerite Earths	Ceria	0·4	0·9
		Lanthania	—	6·0
	Ytterite Earths	Yttria ...	—	5·2
		Erbia ...	0·6	1·7
	Common Earths	Chromium ...	0·4	0·4
		Alumina ...	0·6	0·6
Alkaline Earth Metals		Baryta	3·3	3·3
		Strontia	5·2	5·5
		Magnesia	5·0	5·0

at 1-in. pressure. It should be mentioned that only a small difference in size is necessary, and that all the gas-holes should be equally enlarged or closed. The mantle should be gently shaken out of the box or cardboard tube and held by the loop by which it is then suspended over the fork on the porcelain rod, while the bottom of the mantle hangs over the neck of the gallery. The gas must not be turned on and lit until the flame of a spirit lamp has been held to the bottom of the mantle, when the toughening coating upon the mantle will be quickly burnt off and leave the mantle ready for use. All that remains to be done is to fix the chimney straight upon its gallery.

The form of incandescent burner most to be preferred is one with a bye-pass—that is, a small pilot light, which should only be ¼ in. high ; Figs. 99 and 100 show bye-pass burners, the former an ordinary burner, and the latter the new type. In fixing an

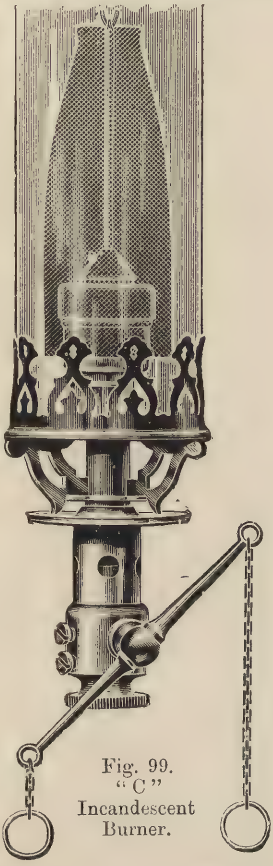


Fig. 99.
"C"
Incandescent
Burner.

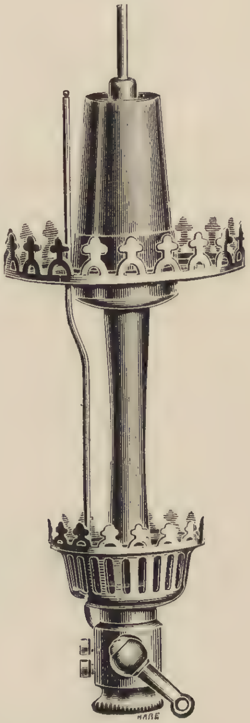


Fig. 100.—Kern Incandescent Burner.

ordinary bye-pass burner, take care that the bye-pass tube up the centre of the Bunsen burner fits properly into the groove in the gallery, or imperfect combustion, and an unpleasant smell, will result. The gas consumption of the bye-pass or pilot light

is insignificant, and is regulated to a nicety by a little screw at the bottom of the burner. A small lever is fitted to these burners for the purpose of lowering the light; sometimes, as in Fig. 99, the lever has chains. Where this form of burner is in use no torch is required, as immediately the gas is turned on at the tap the burner is alight. The bye-pass burner is more economical as regards mantles, as the light is applied to the gas at the best point, and no explosion occurs.

A new Welsbach burner known as the Kern is illustrated by Fig. 100, and differs as is apparent from the older kind or "C" burner, illustrated by Fig. 99. It is supplied with or without the bye-pass, the one illustrated having this important accessory, however. Though the Kern burner differs from the "C" burner in general construction, yet in broad principle it is the same, inasmuch as both, of course, are Bunsen burners. The advantages of the new burner are:—(1) An illuminating power of from 25 to 30 candles per cubic foot of gas as compared with the 16 to 18 candle-power of the "C" burner. (2) A governor is not necessary; increase of pressure involves increase of light, whereas in the "C" burner, increase of pressure in the absence of a governor causes the deposition of soot on the mantle. (3) The new burner does not require a chimney.

The ordinary ("C") Welsbach burner is of three types. First, the actual "C" burner, consuming about $3\frac{1}{2}$ cub. ft. of gas per hour, and giving a 60-candle-power light; second, the "S," consuming $2\frac{1}{2}$ cub. ft. of gas, and giving a light of 35 candles; and third, the "Gem" burner, consuming $1\frac{3}{4}$ cub. ft. of gas, and yielding a light of 35 candle-power. The "New" Welsbach burner is made in the following sizes:—

No. of Burner.	*Gas Consumption at 1 in. pressure. Cubic feet.*	*Illuminating Power in Candles.*
0	$\frac{3}{4}$	20
1	1	30
2	2·2	50
3	3	80
4	3·8	105
7	6·5	185

In transferring a mantle from its box to the burner, take the two ends of the string in one hand and lift the mantle out of the paper tube. By holding the top part of the burner in the other hand and below the mantle, the latter can safely be lowered into position. Before fixing the chimney, examine the mantle, as a faulty one will be exchanged by the dealer if returned before being lit. A mantle is made up of a regular series of loops, each row connected to the one above, and if at any point a loop does not join the row above, the mantle should be returned as faulty, as it is almost certain to develop a break as soon as used. Other faults, such as broken collars, broken suspending loops, fractured sides, and torn bottoms, are noticeable at a glance.

When lighting incandescent burners, a spirit torch should be applied from underneath the chimney, but above the disc which prevents lighting back; the spirit torch does not blacken the chimneys as do tapers or matches. Some people prefer to light from the top of the chimney, in which case the gas should be turned on sufficient time before the light is applied to allow the gas to expel all the air in the chimney, so that little or no explosion shall take place, and the mantle may be free from consequent damage.

The breakage of mantles when in position may be avoided by attention to a few rules. Fix incandescent burners only on good sound and clear gas fittings. Where there is much vibration, use one of the anti-vibration frames now on the market; these frames are specially suitable for hanging lights, such as the arc lamps, etc. All pendants for the incandescent light should be supplied with cup and ball joints, and they should never be screwed stiff, or the mantle will break if it gets the slightest knock. In draughty places, such as lobbies, passages, and corridors, a mica chimney is desirable, so as to avoid breakage of the chimney, and to preserve the mantle.

If a newly fixed burner gives an unsatisfactory light, either there may be an insufficient gas supply, or the mantle may be much too wide; perhaps both conditions exist. In the first case the mantle will be well lit all round the bottom with the light getting worse towards the top. If two of the four air-holes in the Bunsen tube are covered by the fingers, the light will at once improve. Therefore, either reduce the amount of air admitted, or increase the quantity of gas supplied. To reduce the amount of air, unscrew the Bunsen tube and fix inside it a piece of card or tin to cover

two opposite holes. To increase the gas supply, remove the burner from the fittings, and unscrew the Bunsen tube, when the gas regulator nipple will be seen to consist of a brass tube having a soft white metal top with five small holes, which should be very slightly enlarged. Very handy for this purpose is a hat-pin, ground to a long taper and passed up from the under side. When a mantle is too wide, one side only is incandescent, the other side hanging away from the gas ring. This fault is, of course, easily seen before the burner is used; if, however, the mantle has been lit, the light can be improved by slightly lowering the mantle and, as this is tapered, presenting a smaller surface to the flame. Take off the mantle, lifting it by a wire under the suspending loop. Then place the wire across a glass tumbler with the mantle suspended inside. Take out the support, nick it with a file about $\frac{1}{2}$ in. from the plain end, and break it off. Finally replace the mantle, etc.

It is noticed that the brilliant light given by a new burner does not last, the light after a fortnight probably commencing to decrease; if kept in use, the mantle top becomes coated with soot and a smoky flame issues. The burners go wrong in a much shorter time if used in a room in which a fire is constantly burning. The cause of this is simply dust, which is drawn in at the air-holes and carried up the Bunsen tube. It cannot pass away owing to the gauze, to which it adheres, thus preventing the gas getting away quickly enough to draw in the proper amount of air. To remedy this, take off the mantle and, with a small brush (an old nail- or tooth-brush), remove the dirt, blowing through the gauze afterwards. Then replace the mantle, clean and replace the chimney, unscrew the Bunsen tube, and brush the nipple clean. Blow the dust from the tube and then refix the top. If the mantle is covered with soot, leave the gas half on until the soot is removed. To keep the burners at their best, this process should be done at least monthly. If the burners are in a dusty place they will require more frequent cleaning.

Failure of the bye-pass is a common fault, even in new burners. The bye-pass light may go out after the gas is turned on. In a new burner this is often caused by one of the two set-screws on the side of the burner being inserted too far; in this case, after unscrewing a complete turn, the burner will most likely work. It is sometimes necessary to take out both screws and to remove the grease adhering inside the end of the hole.

CHAPTER VIII.

GAS-FITTING IN WORKSHOPS AND THEATRES.

In fitting workshops with gas, it is important that strong materials be employed, and it is desirable to use iron pipes throughout. Where a row of benches is fixed upon each side of a workshop, it is usual to run a pipe along just below the ceiling, with tees between each window; from these a small pipe is carried down to either a single or double swing iron bracket. Some firms who make gas-fittings supply iron brackets, but they can be made up quickly from the brass fittings and short pieces of iron pipe purchasable from any dealer. Brass swivels wear considerably better than those that are made of iron, and do not corrode and stick in the working parts.

When the lights are to be fitted, say, down the middle of a workshop where lathes or other machine tools are used, the only brass parts are the taps and burner elbows, the ordinary iron tee being very suitable for the centre of the pendant. Where more than one floor is to be lighted, fix on the supply pipe a governor for regulating the quantity of gas delivered; otherwise the pressure due to the height of the upper floors will cause a lowering of the light in the ground floor or basement. It is also an advantage to have each floor separately supplied from the main, so that each floor may be shut off entirely without interfering with the others; and if a separate meter be supplied for each floor, the quantity of gas consumed in proportion to the work done after dark may be checked, and any escape noted. Where a pipe falls, a pipe syphon or syphon-box should be fixed, as the temperature is subject to extreme changes and the quantity of condensation is much greater than in private houses.

When the pipes are run through the floor and up the legs of the lathes or other machinery, it is usual to bend the pipe to the

exact curves taken by the machine, and to fix the pipe in its place by means of bands of iron bent to the curve of the pipe, and fixed to the machine by two small set screws. These bands may also be found useful in fitting up houses where the nature of the wall or floor will not permit the use of the ordinary pipe-hook.

It is often found necessary to fit up in a workshop over each machine a bracket arranged so as to move in any direction to suit the convenience of the workman. One way of making these fittings is to make the elbows of the brackets of two double swing swivels—one upright and one on its side. Another way is to have two lines of pipes from the support, and to connect both at each end to double swivels; whilst between the upper and lower pipe, and laid at an angle, is a thin bar, which is fixed on to the upper pipe, and can be clamped to the lower one when the exact position required has been obtained. This form of bracket is useful in drawing offices, where the burner and shade commonly in use cause the other pattern of bracket to gradually fall downwards on to the table; whereas the second arrangement always keeps parallel, and, if tightly clamped, cannot change its position without breaking the thin metal bar, which should be made sufficiently strong to withstand the strain due to the weight of the heaviest burner, chimney, and shade likely to be placed upon it.

In making brackets and pendants, it is convenient to know a quick and efficient way to bend iron pipes. The exact shape required having been drawn full size upon paper, the latter is tacked or pasted on to a rough board. Strong cut nails are then driven in to follow the desired curve, the nails being half the outside diameter of the pipe from the drawn line, so that the centre of the pipe, when bent, may lie directly over the drawn line. The iron pipe is heated in a forge fire or in a draw-furnace; the latter heats the pipe equally over the length required. The end is inserted between the lines of nails, and, with the aid of a pair of pliers, is quickly made to follow the curves indicated by the nails. Nails are not necessary on the outer side of the curves, except at the starting point, where a firm grip of the pipe must be insured. Where many pipes are to be bent to the same shape, the board is replaced by a square plate, with holes all over it, cast- or wrought-iron curves replacing the nails. The saving in time and the accuracy of the bending soon repay the

additional outlay. In bending iron pipe, proceed gradually, and make only small curves at a time, or the pipe will collapse.

For workshop brackets, the ordinary circular back or wooden pattress is not employed generally, metal backs being found stronger and more suitable. These metal backs are supplied with the fittings, and are drilled and countersunk ready for erection, space being left for the pipe to screw into the top of the swivel joint. A metal back makes a strong job, and answers every purpose where very neat finish is not necessary.

In all workshops ventilation is a prime requisite, and must be provided for, more especially where the rooms are low and a considerable number of workmen and gas lights are employed. Gas is an excellent draught inductor; an ordinary batswing or union jet burner (see pp. 99 to 107) consuming 1 cub. ft. of gas per hour, when placed in a 6-in. ventilating tube 12 ft. long, will cause 2,460 cub. ft. of air per hour to pass up the tube; and this induced draught can be easily adapted for the removal of the heated and vitiated air from the upper portion of the room. Each person present will give off per hour about 17·7 cub. ft. of air, of which from ·6 to ·8 of a cubic foot will be carbonic acid (CO_2); the amount of CO_2 evolved from the combustion of coal gas practically is equal to one-half the quantity of gas burnt; and an ordinary gas burner may be considered as being equivalent to at least three adults in its effect upon the atmosphere. The air space required in a workshop is 250 cub. ft. for each person during the day and 400 ft. at night. Again, 500 cub. ft. of fresh air per person should be delivered into a room during each hour, and therefore the same quantity of vitiated air must be drawn away by some means; no method is more suitable or so effective as the one above proposed, in which a lighted gas burner is enclosed by a ventilating shaft. A well-constructed Sun burner (see pp. 115 and 116) has an excellent effect upon the ventilation of a room, workshop, or hall, when a properly arranged vertical shaft, usually of sheet iron, is carried up through the roof, and will at the same time assist greatly in the general illumination of the apartment.

Many of the above remarks are equally if not more applicable to the fitting up of theatres and places of public entertainment, whose ventilation is an important matter. In these places, the object to be attained is complete ventilation without loss of lighting effect.

In theatres, it is usual to bring the supply up on the wall on the prompt or right-hand side of the stage when looking from the auditorium, and there to branch off with a tee which has on each side other tees fixed as close together as possible, and all pointing upwards. From the outlets of these run the various supplies to the different parts of the house. This arrangement provides against fire, and is indispensable when it is necessary to lower lights in certain portions only of the stage and auditorium. Each pipe has a cock upon it, and also a bye-pass with a small tap, so that, on turning down the lights, sufficient gas flows through the bye-pass to keep only the smallest flicker in each

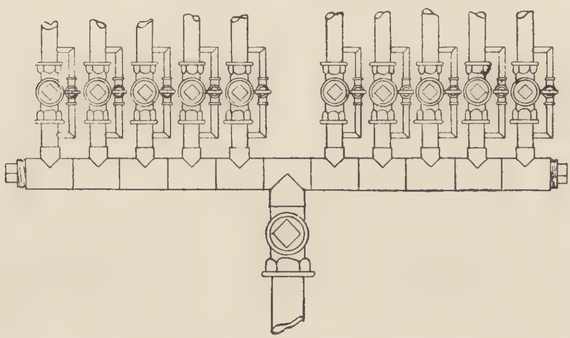


Fig. 101.—Gas Cocks and Bye-passes for Theatre.

burner, and then, when the cock is turned on again, the lights are quickly at their full power without the trouble of re-lighting. The usual way of fixing these bye-passes is to screw an elbow nose-piece into a hole drilled and tapped in the pipe below the cock, and to screw another in the pipe above the cock, taking care that the distance between the two ends, when turned towards each other, is the exact distance to suit a small cock with a union on one end. Fig. 101 explains the arrangement. Each supply pipe is labelled with the name of the portion of the house which is being served by it, so that the gas may be turned off or on as may be required.

Fig. 102 illustrates another form of bye-pass arrangement. It is fixed about 5 ft. from the floor of the stage, as handy as possible. The reservoir is filled direct from the main by the

pipe L, whose size depends principally upon the quantity of gas required for the stage. The footlights, gas battens, and side-lights are all kept separate: E controls the footlights; F, side-lights; G, batten No. 1; H, batten No. 2; I, batten No. 3. Should there be any lights in the front of the house controlled from the stage, they should follow batten 3 or 4, as the case may be, as at K. For a stage with a 15 ft. by 20 ft. opening, the reservoir D should be 2 in. gas barrel, reduced to $1\frac{1}{2}$ in., with reducing socket on to the main. E, F, G, H, I, K would be $\frac{3}{4}$ in. barrel. The letters N N denote the bye-passes of $\frac{1}{8}$ in. barrel tapped into the $\frac{3}{4}$ in. pipes. The taps, of course, must fit the different sizes. It will be seen at a glance how easy it is to

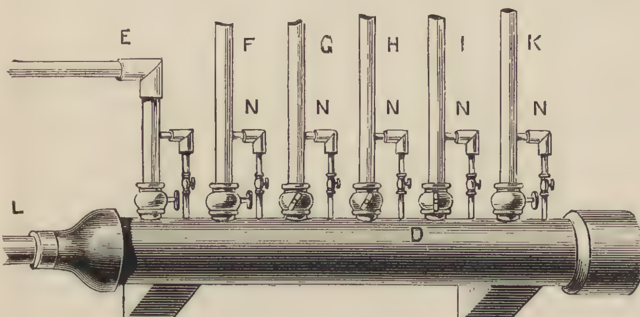


Fig. 102.—Gas Cocks and Bye-passes for Theatre.

regulate the gas with this arrangement. The bye taps N must be kept full on; the main taps may be turned as low as is wished—right off, if need be, the bye taps preventing the light going out.

It is usual in theatres to guard all bracket lights in the passages and corridors, behind the proscenium, leading to the dressing rooms, property and painting rooms, as well as the lights in these places and the carpenters' room, by means of a wire frame made of the same shape and size as an ordinary glass globe. So many inflammable articles are moved about in a theatre that every possible precaution has to be employed.

A theatre stage must be lighted so as to ensure a broad open light, in order that shadows may not be cast on the floor or scenery by the actors or by any articles on the stage. Thus, a

stage is lighted from the front, at the top, and at the sides, the respective names of these lights being: footlights, gas battens, and sidelights. All these must be protected to prevent accident from fire.

Stage footlights are formed of 1 in. or 1¼ in. gas barrel. Strike a chalk line from one end of the gas barrel to the other, and on this line holes should be drilled and tapped to receive the ordinary 5 ft. per hour gas burners, which should be from 4 in. to 6 in. apart.

It is often found useful to have more than one row of footlights upon the front of the stage, as in Fig. 103, and then argand

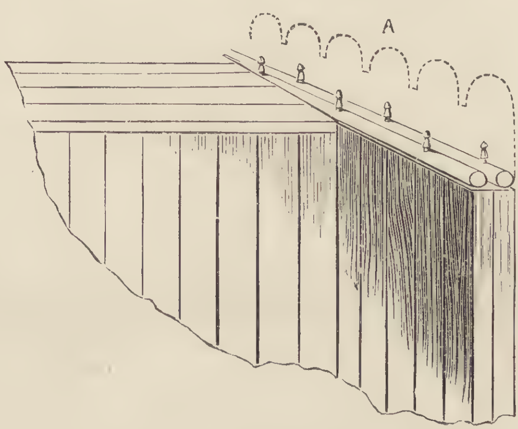


Fig. 103.—Stage Footlights.

burners are usually employed, each row having different-coloured glasses, so that the light thrown may be of the desired tint (see Fig. 104). The usual colours employed are green and red, these forming useful evening effects when the exigencies of the play require them.

Footlights should be laid about 4 in. or 5 in. lower than the stage floor (see Fig. 103), so that the bottom part of the actual light may be on a level with the floor of the stage to prevent the floor being in shadow, as it would be if the lights were too low. The lights are guarded from the view of the audience by means of a board on edge or a strip of scolloped sheet zinc. The side nearest the stage is guarded usually by means of brass

uprights and two or more brass tubes running through them, and to this is sometimes fastened brass-wire gauze to prevent small articles and ladies' dresses from catching fire. The trough in which the gas barrel lies should slope down from the stage The

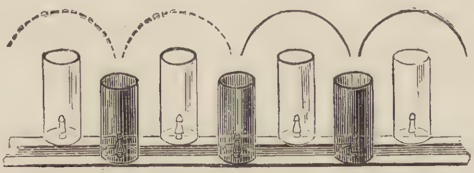


Fig. 104.—Two-row Footlights for Stage.

reflectors are fixed to the front of the stage behind the light (see A, Fig. 103).

In fixing footlights to a portable stage, the trough should be hinged to the front of the stage and supported by acute angle brackets (B, Fig. 105), which allow the trough to hang down to the

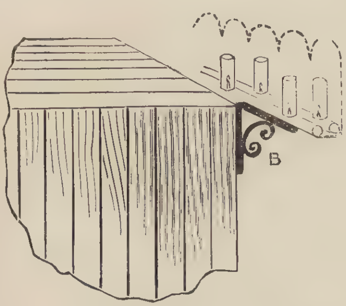


Fig. 105.—Footlights for Portable Stage.

Fig. 106.—Stage Footlight Reflector.

required level. The reflectors, which are fixed to the upright front of the trough (see Fig. 103), should be of zinc, and may be separate or in one length, and scolloped to break the line as desired. For a portable stage it is usual to have separate reflectors, as illustrated by Fig. 106, in which C C are two pins soldered in the zinc for fixing in holes made at regular intervals behind each

light. The end of the gas barrel is connected by indiarubber tubing to the main supply pipe.

When rehearsals take place in the daytime and there is insufficient light to properly watch the action, it is usual to fix up a T-light standard upon a cock in the centre of the footlights. This standard may be made of 1-in. or $1\frac{1}{4}$-in. pipe, and should be about 4 ft. 6 in. or 5 ft. high. Upon this is screwed a T, and a piece of pipe about 18 in. to 2 ft. long is screwed into each end of the T and drilled and tapped, burners being put in about 5 in. or 6 in. apart. This will usually give sufficient light for the purpose.

The flies, as the portion of the stage where the sky borders usually hang is called, is lighted by gas battens, the arrangement consisting of a length of pipe the full width of the stage, with holes drilled as before described, and burners inserted. These pipes, which are hung across the stage between each border, are usually connected to the side and rising supply pipe by means of rubber tube, and are hung on pulleys so that they can be easily raised or lowered as required. The gas battens must always be hung with chains, not only to guard against fire, but also because the gas so soon rots cord that the batten might fall at any time, with dangerous results. These lights, again, are guarded with gauze wire, a sheet of wrought iron being fixed on the side nearest the border or audience, and the portion facing back being guarded with iron-wire gauze.

Of sidelights there are either three or four behind each wing. A perpendicular gas barrel rising from the stage is tapped for the burners. Sidelights must always be protected with wire globes (see Fig. 107). Sidelights may be dispensed with, particularly on a small stage, as they are dangerous in a limited space. Sidelights are for illuminating the wings, so that the shadow of one wing shall not fall on the other; but this effect may be gained by the proper arrangement of footlights and gas battens.

For lighting the auditorium it is customary to use a large gasalier, often of very great weight, which requires extremely careful fixing, as should it fall it might possibly kill many people. Another system of lighting is by means of a Sun burner (see pp. 115 and 116) in the centre instead of the gasalier; and no matter which arrangement is adopted, a large wrought iron flue should be constructed, with a cowl on top to prevent down-draught and the entrance of rain. This not only serves to remove

the products of combustion from the gas-burners themselves, but, by the heat engendered, will cause a strong upward current of the vitiated and warm air from the body of the theatre. In some cases in which electric light has been fitted in theatres it has been found necessary to retain the gas centre-light so as to ensure efficient ventilation.

In the larger theatres it is often found necessary to supplement the centre gasalier by brackets, having two or more arms, fixed around the fronts of the different circles and galleries; these brackets are served generally by a pipe carried from the

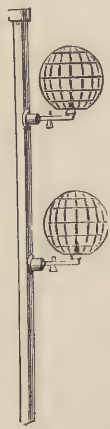


Fig. 107.—Stage Sidelights.

general supply centre on the prompt side of the stage, around the inner side of the balustrade and along the immediate foot of it. Where the galleries are deep, brackets are fixed frequently on the back wall of the auditorium, so that the back portion of the house is not in absolute darkness, and the way out of the theatre may be seen more easily. Much, of course, depends on the amount of money which it is intended to spend upon the lighting; but every effort should be made to ensure the work being carried out in a thorough manner, as a great deal of expense may be saved if the work be properly done in the first instance.

In almost all large size theatres a gasman is kept on the

premises, who is answerable for the soundness of the pipes and fittings; he is required to test periodically the pipes and fittings for leakages. This testing must not be done with a light, but at a time when gas is not being burnt anywhere in the theatre; then by carefully noting if any gas is passing through the meter (by noting the movement, if any, of the small leaden disc above the ordinary index, or the small dial if it be a dry meter) it may be ascertained at once if any gas is being lost through leakages in the pipes. Another way of detecting leakage is to use a pressure gauge, and note the pressure (1) when the gauge is first fixed on the outlet side of the meter (the latter should be closed off), and (2) after the lapse of say half an hour, when if there be any leakage the pressure will have fallen to nothing. There are small meters with large hands for the sole purpose of testing for leakage, and these, by indicating to a very fine degree, readily show the rate of leakage. One prominent firm manufactures a small holder which can be connected to the outlet side of the cock to the meter, and filled with gas before the gas is shut off; then any leakage is made up out of the holder, which lowers quickly, as it is only made to contain one-tenth of a cubic foot of gas—a scale upon the side showing the actual quantity which has been required to make up for the gas which may have leaked away.

In treating upon theatre lighting by any method, only generalities can be touched upon, as so many different arrangements are now found in theatres and music-halls, each depending to a large extent on peculiarities of the building and on special requirements.

CHAPTER IX.

GAS-FITTING FOR FESTIVAL ILLUMINATIONS.

On occasions of public rejoicing, it is customary to illuminate the streets and the fronts of houses. Gas is the illuminant commonly employed, and the work of preparing and fixing the fittings is entrusted, as a rule, to the ordinary gas-fitter. An effective system of lighting up buildings is to employ rows of pipes, with arches over doors and windows, the pipes being of wrought iron of about ¾ in. to 1 in. bore, with holes drilled at intervals of 6 or 9 in., into which holes short pieces of brass pipe are screwed. These pieces of pipe are bent with the free end upwards to hold a burner and to support a gallery carrying a moon or globe, generally of opal, but sometimes of ground glass. This system of lighting up buildings is very effective when a large front has to be covered; but, should rain fall, the hot globes will quickly crack.

In making gas illuminations with an elaborate motto or device shown out in flame, the first requirement is a large-sized pipe, so that an ample supply of gas may reach the burners; an insufficient supply of gas will spoil the device. The pipes leading to the different parts must be sufficiently large and numerous to ensure plenty of gas at all parts of the design, at (as nearly as possible) equal pressure.

The design to be attempted may be a star, a crown, initials, or a portrait, or perhaps a combination of all, with a motto on a ribbon entwined about the stars, etc. As regards the making of a star, the first thing is to make a full-sized drawing in ink, on paper, of the device. This drawing can be enlarged from a small sketch by means either of a pantograph or of small squares ruled upon the sketch and also upon the paper in proper proportion, each square being numbered. The various lines crossing each square can be easily drawn to cross the similar square on the larger paper.

Having completed the design, decide how the gas can best be led to the different parts of the design so that all may be equally well supplied ; in this lies the secret of success. A good working rule is to consider that there cannot be too many sources of supply. The usual plan is to make an inner circle of copper tubing, copper being used because it can be bent easily and yet can stand the heat of the gas burning from holes in it. This inner circle is then brazed where the ends of the ring meet. The method of

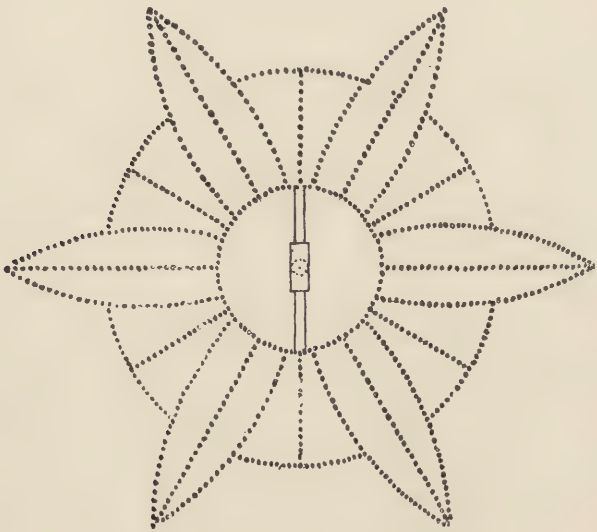


Fig. 108.—Star for Festival Illumination.

brazing is to place the copper pieces on a tray of charcoal and then to turn the blowpipe burner upon the parts until they are red-hot ; place some spelter and powdered borax upon the part where the joint is to be made, and continue the heating until the spelter runs, more spelter being added until the joint is complete. Where two ends are to be joined together, it is usual to put a thin coating of spelter upon each before bringing them together, when the joint can be quickly made.

The ring being completed, the connection for the gas is usually brought up to the centre, an iron T-piece fixed there

for the supply, and copper pipes screwed into each end of this T. These copper pipes, after being cut to the right length and shaped at the ends, are fitted into the ring (which has also had two holes cut in it, opposite each other), and then are brazed. The foundation of the device is now complete, and if a simple star is required, the radial pieces are cut to the necessary length, and each is shaped to the curve of the pipe of which the ring is composed—usually of a somewhat larger diameter than the radial pieces. The outer ends of the radial arms may be closed by being squeezed tightly together in a vice until the two sides become almost as one piece.

The drilling of the holes, if the device is only a small one, is

Fig. 109.—"V.R.I." for Festival Illumination.

done when the construction is complete (see Fig. 108). This operation requires care, and the drills used must be very small in diameter. They are usually only about the size of an average needle, and, for drilling copper, are best sharpened not, as might be supposed, upon an oilstone, but better upon the ordinary grindstone, or with a fine file. Sharpened in this way, they last much longer and cut more quickly. Of course, in large factories where these devices are made, special machines are to be found which revolve at very high speeds and do the drilling very rapidly ; but where only a few are to be turned out, probably one of the Archimedean or American drill stocks will be used, and the drills themselves will be made from ordinary household needles. If the holes are too large, the general effect is greatly spoiled ; whilst if the holes are too small, the wind will easily

blow out parts of the gas-flame. Holes of the same diameter as are found in a No. 1 or No. 1½ gas-burner will suit the purpose.

When all is finished, the device should be tried with gas—under, if practicable, the same pressure as it is likely to receive when fixed in position—and the general effect noticed. Any holes that are too small can be reamed out, or re-drilled, and any that are too large may be closed by a tap from a hammer.

Perhaps the simplest form of illumination device is one made by merely bending the copper pipe in the hands. This flexibility

Fig. 110.—"V.R.I." Monogram for Festival Illumination.

is one of the advantages of copper over iron or brass; iron, moreover, has the disadvantage that it rusts, and the holes get quickly clogged up when exposed to the weather. By arranging that the bends are never too sharp, a series of letters can be made without the necessity of brazing, except, perhaps, here and there, to give an even supply. By remembering that curves can be left undrilled if necessary, much can be done in this way, especially if the uniting form of letters is adopted. Fig. 109 is an example of this class of work. The designs shown by Figs. 110 and 111 are specially suitable for street illumination, while others are the Prince of Wales' feathers, crosses, and stars of all patterns and of various

numbers of points, suitable dates composed of numerals, V.R. and V.R.I. in all kinds of letters, from the plain block to the most ornately flourished, with ornaments and portraits. These last require more special care in order to catch the likeness, and necessitate very expert bending and drilling.

Transparencies also provide a favourite form of illumination, as they do not burn so much gas, and are nevetheless very effective. They should be painted in oils on thin and even-

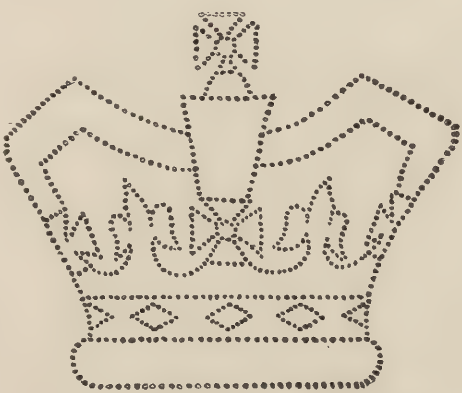


Fig. 111.—Crown for Festival Illumination.

textured canvas, using only such colours as are transparent, and avoiding most, if not all, of the earth colours. The canvas is stretched upon a frame, and a sheet-iron band is fixed all round this, to prevent the gas jets, which are placed behind, being seen from the side, and so spoiling the effect of the transparency.

It is customary for gas-fitters who are likely to be fixing gas illumination devices to give early notice to the gas companies of the requirement of special services from the main.

CHAPTER X.

GAS FIRES AND STOVES FOR WARMING AND COOKING.

An examination of the principles of gas stoves, and a consideration of the advantages and disadvantages of these heating appliances, may appropriately precede any description of gas stoves themselves. A point often ignored in the heating of rooms is that a room will not feel warm until its walls reach the same temperature as the air which it contains. Until this occurs, the room will feel draughty, owing to the fact that the walls are depriving the air of the heat given out by the stove.

It is necessary to examine the conditions of the room or building to be heated before making any calculation as to the amount of gas required to heat it. Architects calculate the cubical contents of the room, and gauge from this the size and character of the heating appliances required. This method, however, has been shown by that expert in gas fuel, Mr. T. Fletcher, F.C.S., to be fallacious, and his contention has been borne out by independent observation. A better plan is to calculate the area of the wall surface, and, in ordinary dwelling-houses, allow that one-half a thermal unit is absorbed by each square foot per hour for each degree Fahrenheit rise after the necessary warming up is complete.

The number of heat units generated per cubic foot of gas of sixteen candle-power, as supplied in London, theoretically is 670 to 680; therefore, to raise the temperature in a room which has been once warmed, it is necessary to allow a consumption of 1 cub. ft. for every 1,300 sq. ft. of wall surface. For the preliminary heating, however, considerably more than this is required; and as there should be a change of air in the room about every twenty minutes, practically three-fourths of the heat produced by the stoves passes away by ventilation, and consequently about four times the above-mentioned quantity of heat is required to

raise the temperature of a room from the commencement, when it is at about the same temperature as the external air.

It was at one time recommended to fix a row of Bunsen burners in front of or underneath an ordinary coal fire-grate, filled either with black fuel, made of fireclay, or with small coke. The coke was suggested by Dr. Siemens; it gave a very cheerful appearance, but it was found that the quantity of coke used, together with the consumption of gas, rendered the plan uneconomical. Many persons set a high value upon the cheerful appearance of this arrangement, and are willing to pay for it; and makers have brought forward improvements by which a saving of gas is effected. Still, gas fires in ordinary coal grates can only be recommended in preference to gas stoves when economy is not essential.

Sugg's "Charing Cross" gas fires, Fig. 112, p. 144, are constructed on the principle just explained. A section of a somewhat similar gas fire is shown by Fig. 113, p. 145, in which A indicates the special fireclay back, the lower part of which forms the channelled bottom of the grate (see Fig. 114, p. 146). The bottom layer of asbestos lumps is laid on the ridges, the channels being left unobstructed. The burner flames play into the channels and are directed towards the back of the fire. By means of the projecting back the whole of the fire is brought to the front of the grate, and the heat, instead of passing up the chimney, is deflected by and radiated from the back, and so made to assist in raising the asbestos to incandescence. A four-burner "Charing Cross" gas fire (Fig. 112, p. 144) is stated by the makers to consume at full power not more than 27·7 cub. ft. of gas per hour; but, even on a cold night, a bedroom containing 1,920 cub. ft. of air space, after being warmed to 60° F., can be kept at that temperature by the hourly consumption of only half that amount of gas.

Stoves in which air passes over heated surfaces are more economical than ordinary gas stoves; but, on the other hand, they are more liable to cause unpleasant odours through the heating of the dust particles. With these stoves, as also with hot-air and hot-water pipes, as distinct from grates, the heated air has a great tendency to rise to the top of the room, leaving the feet cold while the head is too warm. The same effect is noticed where enclosed stoves are set forward some distance into the room; but these stoves are very economical, and where fuel is dear this is a paramount consideration. One pound of coal burnt in an

ordinary grate requires, for its proper combustion, 300 cub. ft. of air having a temperature of 620° F.; and 1 volume of gas for complete combustion requires $5\frac{1}{2}$ volumes of air. In atmospheric

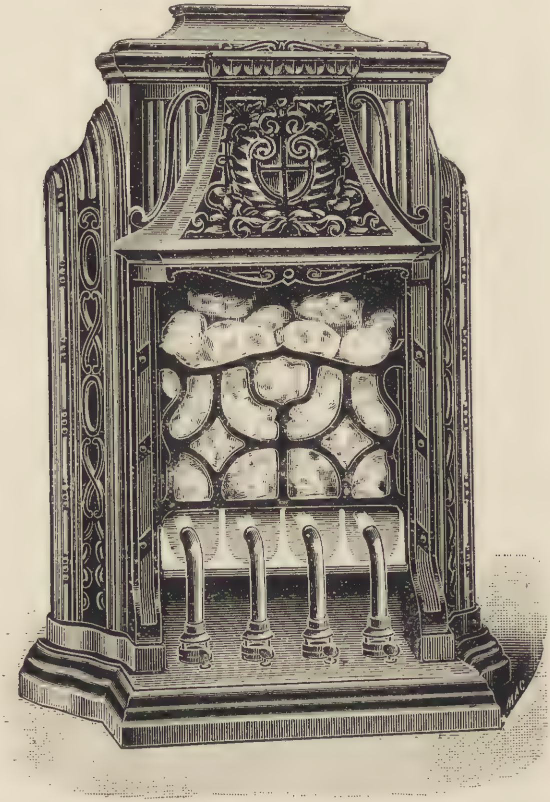


Fig. 112.—"Charing Cross" Gas Fire.

or Bunsen burners the average mixture of gas and air is 1 volume of gas to 2·3 volumes of air; consequently, a further supply of air around the flame is necessary to cause complete combustion, and an analysis of the gases, taken from the centre of the glowing fuel, shows that often 10 per cent. of carbon monoxide exists, and, should

down-draughts occur, this must find its way unnoticed—for it has neither smell nor colour—into the room; hence the necessity for ensuring a good draught from the stove, and for the use of a good

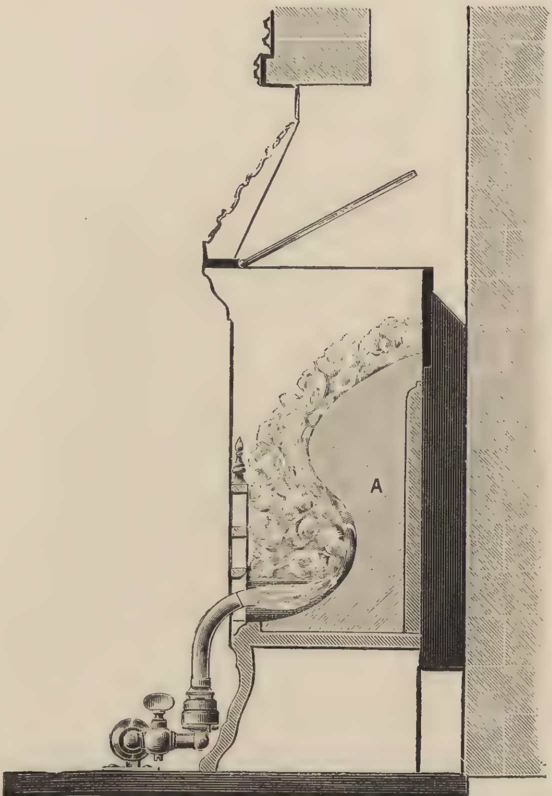


Fig. 113.—Section of Gas Fire in Coal Grate.

cowl, as described in connection with the regenerative lamp, in order to prevent down-draught. Curiously enough, however, the analyses of gases in the flue during the burning of the gas stove do not show a trace of this deadly gas. An average of some twenty-four stoves tested in this way showed the presence of

12 per cent. of oxygen, 84 per cent. of nitrogen, and 4 per cent. of carbonic acid, thus proving that all the carbon monoxide had been converted into carbonic acid before leaving the stove when burning in the proper manner. This shows conclusively that flues are a necessity with gas stoves in which Bunsen burners are in use, although they need not be so large as the usual coal-grate flue ; but where flues are not possible, only such stoves as employ ordinary lighting burners and utilise the heat radiated from a polished surface should be fixed.

With Sugg's "St. Martin" reflecting stove (Fig. 115) it is advisable to employ a flue, though this can be dispensed with

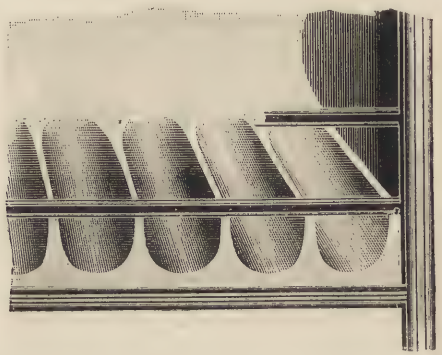


Fig. 114.—Channelled Bottom of "Charing Cross" Gas Fire.

in a well-ventilated room. This stove has luminous flat-flame burners, each fitted with a separate governor and tap, which ensure a uniform gas consumption however the pressure may vary ; it has a bright and cheerful appearance.

Where a smoky chimney exists, a gas stove will not cure it, unless the fault is due to a contraction of the flue, by which the flow of the draught is impeded. In that case a much smaller flue for carrying off the products of combustion being sufficient with a gas stove as compared with a coal fire, the trouble will probably disappear ; but it would be well to ascertain the origin of the fault before recommending the adoption of a gas stove as a remedy.

Most authorities are agreed that radiant heat is the best and

healthiest, and therefore such stoves as afford this kind of heat are preferable to those that impart heat by convection. By radiant heat is meant heat that radiates directly from glowing coals or other incandescent material and passes through the air without influencing its temperature to any appreciable degree. Radiant heat coming in contact with persons, walls, furniture, etc., warms

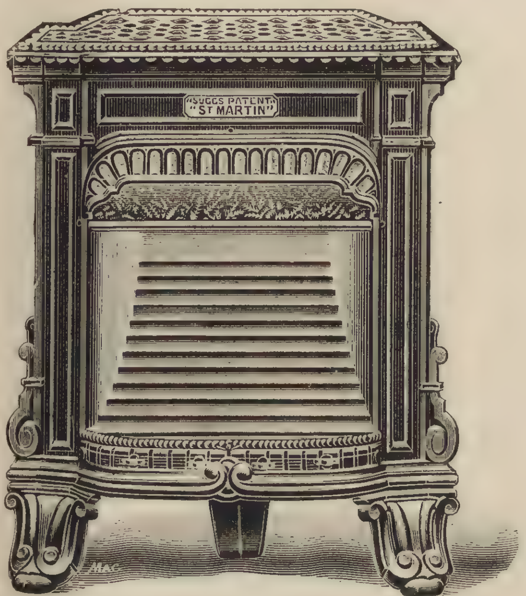


Fig. 115.—"St. Martin" Reflecting Gas Stove.

these objects, but leaves the air comparatively cool. Heat by convection warms the air itself.

The cleaning of the burners and rearrangement of the asbestos or clay blocks is a necessity in all gas stoves, and such stoves as are fitted with separate burners, each controlled by its own tap, are much to be preferred to those in which only one burner is fitted, and which have a pipe with a series of holes from which the gas issues. These latter are all right when turned full on, and with a good pressure; but should the pressure fall from any

cause, or should it be desired to turn down the gas, the burner is very liable to "light back"—that is, the light runs back to the point inside of the Bunsen burner where the gas issues before it has set up the injecting action by which it becomes mixed with

Fig. 116.—Fletcher and Russell's Gas Fire.

air—and when this is the case a most objectionable smell is given forth. Several inventions have been brought forward with the object of preventing this lighting back, principally by means of wire gauze inside the burner, and these contrivances are effective so long as the pressure does not fall below $\frac{4}{10}$ in. of water; but the arrangement with separate burners allows of a much larger

range of temperature, and consequently of much nicer adjustment of the heat of the room.

Fletcher, Russell & Co.'s H.R. pattern gas fire (Fig. 116) is an example of a stove giving radiant heat only. It has an incandescent iron fire, to which gas is supplied by a ½-in. pipe. Made

Fig. 117.—"Senegal" Gas Stove.

by the same firm is the "Senegal" stove (Fig. 117), which gives forth both radiant and convected heat. In the latter kind of gas stove, and, indeed, in all stoves using clay or asbestos fuel, the position of the blocks is of much importance. They should always be so placed as to ensure that the flame has a free flow and is not checked too rapidly, or it will prevent the proper combination

with oxygen of the air to form carbonic acid, a portion of the heating power of the stove will be lost, and a quantity of carbon monoxide will be allowed to escape either into the room or up the flue. Clay blocks have been found, after a series of tests, to be superior in heating power to either asbestos fibre or iron grids; and there is a form in which fibres of asbestos worked up with the fireclay enable the blocks to be made much thinner, and at the same time, acting in the same way as the hair that is mixed with plaster, keep them from breaking. The asbestos or clay may vary in shape, but as a rule it is in the form of balls or eggs; the egg-shaped clay blocks are hollow, as in Fig. 118; generally the

Fig. 118.—Egg-shaped Clay Block.

asbestos-clay balls are solid with one large hole through them. Also, the fuel is in the form of baskets, etc. A bowl of water should always be kept in front of the gas stove, so as to compensate by its evaporation for the drying effect on the atmosphere.

It is essential that, wherever gas is burned, the pressure shall be ascertained at which the greatest economy can be obtained; and it is then advisable to try to obtain an even supply of gas at that pressure under all conditions. Where several gas stoves are in use, this point demands attention still more urgently. To ensure this even supply, a governor should be fixed, either at each stove or near the meter, by which the pressure may be regulated.

Gas fires are usually fitted in the fireplace of the room. The wrought-iron flue is carried up into the ordinary chimney, the supply being brought along under the floor to the side of the

hearth, and connected to the supply pipe on the stove by a piece of tube bent so as to fit into the angles of the mantelpiece and stove. This tube has upon it a small cock, either close alongside the stove or—what is better—a cock is fitted under the boards and a little sunk plate is let into them, in which the T top of the cock is protected from harm; a small hinged lid giving access to the tap as required. A convenient form of quadrant cock for connecting the supply pipe to the gas fire or stove is illustrated by Fig. 119. With this cock the supply of gas can be regulated to a nicety.

The hissing noise heard in the burners of gas fires is caused by the velocity with which the gas issues through the orifices of the burners. The defect may be remedied to some extent by fixing a

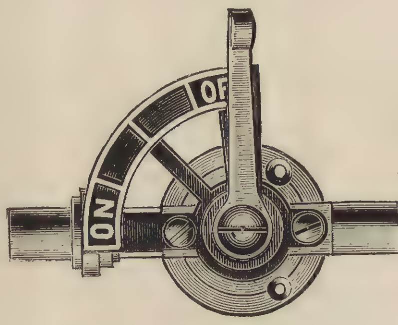


Fig. 119.—Quadrant Gas Cock.

governor on each burner, or by checking the gas supply when the burners are turned full on by means of the main tap on the meter. A plan which has been tried with success is to have a tap fixed on the service supplying the fire, some 8 ft. or 10 ft. away from the latter, to turn the burners full on, and to reduce the pressure by the tap. Sometimes a gas fire will roar because the interiors of the burners are rough, the result of a burr in the tube or of an accumulation of deposit caused by the burners firing back.

It is frequently found that the supply of gas to stoves is much too small. No gas stove should have less than $\frac{1}{2}$-in. bore pipe leading to it, and this pipe should come direct from a supply pipe of at least $\frac{3}{4}$-in. bore, so as to ensure a free flow of gas and a sufficient supply direct to the stove. In many cases it is advisable to run direct from the outlet of the meter, so as to prevent the

lowering of the lights when the stove is turned on, which might occur if the pipe were taken off one that was heavily drained to supply other burners. The meter must be of sufficient size to enable the consumer to have an adequate supply for the whole

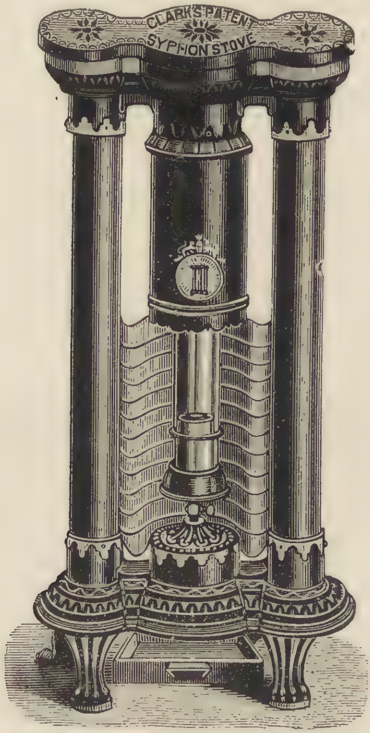


Fig. 120.—Clark's Syphon Stove.

house. For this purpose a pressure-gauge should be employed to ascertain whether there is a naturally high pressure which will supply sufficient gas without an increase in the size of the meter, or whether a larger meter is necessary. A gas stove should not have less than four-tenths pressure, and the pipes should be tested to see that at least more than this is available. It may even be

necessary to go still farther back for sufficient gas, and to have a larger service.

It is impossible in the limited space available to describe all the many types of gas stoves and gas fires on the market Mention must be made, however, of Clark's "Syphon" stoves, which serve to warm the room and to a limited extent to light it as well. As may be seen from Fig. 120, the light and heat are obtained from an argand gas burner, and in the larger stoves there are two of these burners. Through the holes in the top of the stove water may be poured, and the evaporation of this water will compensate for the drying effect exerted by the lighted stove on the atmosphere.

Gas cooking stoves are of two classes: (1) those in which the heat is obtained from non-luminous or atmospheric burners, and (2) those in which the ordinary luminous flames are employed.

The "Eureka" gas cooking stove may be constructed entirely of cast-iron, or partly of enamelled iron or galvanised steel plate. The enamel used does not chip, crack, or scale, and is entirely free from injurious properties. The surface is smooth, and can be readily washed and wiped free from grease. The "Eureka" stoves are double cased at the sides, back, and door, and the space between the casing is filled with a low-conducting material, which prevents loss of heat by radiation, the result being that the gas-consumption is only one-half that of a single-cased stove. The top of the oven is a slab of fire-brick, and the hot air from the oven passes up at the front and over the upper surface of the brick and to the flue pipe at the back. This arrangement economises heat and adds greatly to the efficiency of the oven by preserving equal degrees of heat at the top and at the bottom. The wrought-iron hot plate has movable iron bars polished on the top edge, the whole forming a flat surface on which saucepans and other utensils can be easily moved about. The grilling burner is capable of toasting the two sides of a piece of bread in seventy-five seconds. The "Eureka" stove is fitted with Wright's patent "gate" fittings, by means of which the inside shelf supports are attached to frames, one for each side, which can be lifted out leaving the inside perfectly clear from ledges or recesses. This facilitates cleaning and the removal of grease, etc., another advantage being that the whole space in the oven can be rendered available for baking a large joint.

The atmospheric or Bunsen burner principle in its simplest

form is applied to Fletcher, Russell & Co.'s cooking stove, which, in its more complete form, embodies perfect arrangements for high-class cookery, and is a very quick heater. The oven top is of enamelled porcelain, and is arranged to hold any liquid or grease accidentally spilt, without risk of its running down and disfiguring the front of the stove. The hot plate has an extra simmering burner, and the regulating taps are in front and entirely out of the way. The patent hot-plate bars are fixed or movable at will, as are also the burners and grill plate, the grill being reversible. This stove is supplied in three forms: (1) Single-cased; (2) Double-cased, the space being filled with a low-conductor—slag wool; (3) Double-cased, air replacing the slag wool.

The "Acme" cooker is claimed to have the following advantages: The removable burners have air chambers similar to fixed burners; the removable burner supports (for carriers) rest in pockets, are self-fitting, and do not require screws; the griller is fitted with rising and falling plates; the grill burner is made up of two burners cast in one piece and gives a level flame from end to end; the oven linings are interchangeable, and have incorrodible screw fasteners; the oven gates are interchangeable, so as to be used on either side; but few holes are drilled and tapped, Nettlefold's steel nuts being cast in, so that it is very unlikely for a thread to be stripped.

In the fixing of a gas cooking stove it is of primary importance to see that the gas is supplied at proper pressure. Atmospheric or Bunsen flames give best results at a pressure of $\frac{10}{10}$ in. or 1 in. of water pressure; any lower pressure is liable to cause lighting back. The stove makers usually state the maximum amount of gas consumed by the stove, and the makers' requirements should be complied with. As a general rule, the gas supply pipe must be at least a size larger than the main pipe of the stove, and should come direct from the meter outlet, whilst the pressure should be separately controlled by a governor to a pressure of $\frac{10}{10}$ in. Ventilation is a point to be attended to in the fixing of a cooking stove. A chimney breast, similar to that used with a coal fire, is necessary for the most efficient service, and when a spare chimney is available, a very neat appearance is secured by lining the sides and back with white tiles. A recess on either side of the kitchen chimney breast can be easily adapted for a gas stove by carrying the stove flue pipe through the side into the

chimney. The stove should be provided with a hood having at its top a full-size pipe, which must not be carried into the chimney at right angles. A questionable custom is to put on an elbow and a horizontal pipe. The bend on the top should be easy, and from it the pipe should rise at an angle of not less than 45° above the horizontal, so as to interfere as little as possible with a free up-current into the chimney. One or two elbows and a moderately short length of horizontal pipe on the outlet from the oven are not objectionable, because the draught from that part is strong enough to fan them, but even then the pipe must be as short and direct as possible.

Sometimes a chimney is not available for receiving the flue pipe, and in that case it must be taken through the wall into the open air, a job requiring considerable care and intelligence, especially as regards the top hood; there must be a rising pipe about 8 ft. or 10 ft. high, and this must not be exposed to cold. A sheet-iron pipe exposed to the open air acts as a condenser rather than as a ventilator, by cooling the products of combustion and separating the moisture from it. The deposition of moisture in the pipe gives rise to much annoyance, and the passage is speedily corroded and choked with dust. In order to overcome this difficulty it is necessary to cover any flue pipe exposed in the open air with boiler coating composition. Any pipe that is required to act as a ventilating pipe must be kept warm throughout or its action will be interfered with greatly. The top of the pipe should be covered with a cap or cowl in order to keep out the rain, and should be at least 12 in. away from any wall that may be higher than itself. As ordinary wrought-iron will not last for many years, it is a good plan to use enamelled steel pipes similar to those used on the stoves.

Cooking stoves, wherever practicable, should be fitted so that the smells from the meat or other foodstuffs may pass away up a flue. A hood of sheet iron may be fitted above the stove, at a sufficient distance from the top to admit the largest and highest saucepan likely to be used upon the stove, and a sheet metal flue may be carried from the apex of the hood to the nearest chimney flue. It is usually sufficient to carry this into the kitchen chimney flue, fixing a butterfly valve in the iron flue to shut it off when not in use. The fact that the gas stove is seldom required when the kitchen fire is in use will ensure the proper working of the flue, which should have an elbow turned upwards in the chimney

to prevent back draught. There is usually a small exit provided from the gas stove oven, which may with advantage be connected to the same flue. This is usually provided with a butterfly valve in the stove proper.

There are one or two points which require attention in order to get satisfactory results from a gas cooker. Sometimes the atmospheric burners of a gas cooking stove will not burn properly, and give rise to smoke and smell, this nuisance being usually attributable to the burners being choked with rust, dirt, or grease. If the trouble continues after they have been properly cleaned, it may be found either that the supply pipes are too small or that they are choked. If the oven burners show a liability to be easily extinguished by shutting the door, or from no apparent cause, the fault is either that the dripping pan fits too closely at the bottom so that there is not sufficient air supply, or else that the flue pipe is choked up. There should be no smell discernible where a stove is in use; the cause of any smell that may arise will be found to be accumulations of dirt or grease, or the boiling over of pans or kettles. Care must be taken that all taps are shut off when the stove is not in use. The grilling burners must not be left with the heat deflected downwards unless the grilling tin is in its place, otherwise the heat may injure the top of the oven. The oven burners must be lighted all along, and not at one point only, and the door should be left slightly open for a few minutes after lighting, to allow condensed moisture, etc., to escape. The oven should always be properly warm before anything is put into it. Should the atmospheric burners light back at any time, they should be turned right off for a few seconds, and then relighted.

When ordering stoves, care should be taken to state the quality of the gas being supplied in the district in which the stove is to be fitted, as this condition largely affects the size of the stove burner, all the best-known makers fitting their stoves with burners suitable to the quality of the gas.

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